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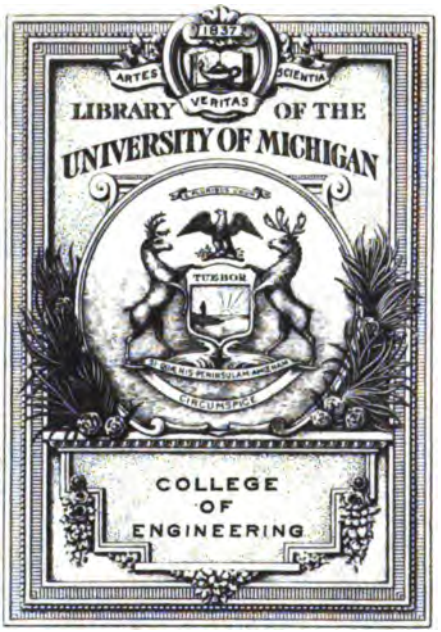

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MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. LXX.

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ERRATA.

Vol. lxvii., p. 524, Note to the Abstract on the "Transmission of Power by Electricity." Correspondence with the Author has elicited the fact that his investigation refers to the *possible* economy of the machine treated of, which will explain some apparent anomalies in the signs used in the equations on p. 525.

,, lxviii., p. 412, line 19, for "headings," read "bendings."

,, lxix., p. 184, line 12, for "Arrab," read "Mokur."

,, ,, ,, ,, ,, 25, ,, "line," read "direction."

,, ,, ,, ,, ,, 26, ,, "nearly vertical direction," read "direction nearly at right-angles with this."

,, ,, ,, 546, line 26, ,, add to this paragraph the following, "Ditto as to the impact of waves on lighthouse towers, 212."

,, lxx., Plate 3, Fig. 5, Jetties at the mouth of the Adour—

,, ,, ,, ,, for "Iron Jetty," read "Iron-Cylinder Jetty."

,, ,, ,, ,, ,, "Iron Cylinders and Girders," read "Iron Trestles and Girders."

,, ,, ,, ,, ,, "Solid Jetty," read "Round Masonry-Piers with Iron Superstructure on old low solid Jetty."

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THE

INSTITUTION

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CIVIL ENGINEERS.

SESSION 1881-82.—PART IV.

SECT. I.—MINUTES OF PROCEEDINGS.

25 April, 1882,

EDWARD WOODS, Vice-President,
in the Chair.

(*Paper No. 1772.*)

"Harbours and Estuaries on Sandy Coasts."

By LEVESON FRANCIS VERNON-HARCOURT, M.A., M. Inst. C.E.

IN the summer of 1880 the Author visited all the principal continental harbours on the North Sea between Calais and Ymuiden, and he has, in addition, examined various sources of information with reference to their past history. As only very slight references have been made in the Minutes of Proceedings to any of these harbours, except Ymuiden and the works at Hoek-van-Holland, the Author thinks that a concise account of their past history, of the means adopted for their improvement, and of their present condition, together with a comparison of the method of dealing with such harbours adopted abroad and in Great Britain, may possess some interest for the Members of the Institution.

HARBOURS.

(Plates 1 and 2.)

On examining the configuration of the English Channel and the adjacent part of the North Sea, it is evident that the portion of the tidal current which flows through from the west becomes considerably confined in the Straits of Dover, and afterwards expands rapidly on entering the North Sea. The flood tide, flowing eastwards along the French and English coasts, being stronger

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than the ebb, washes away material from the shores and cliffs and conveys it through the Straits. On emerging, however, from the Straits its velocity and its range diminish as it expands over the broad surface of the North Sea; and the material which it held in suspension is gradually deposited.

The formation of the numerous sandbanks along the shores of the North Sea, near the Straits of Dover, may be traced to this action (Plate 1, Fig. 1). A sort of equilibrium, however, appears to have been established; and the changes in the banks are very slight so long as nothing is done to alter the normal condition of the coast. According to Mr. Plocq, who has made a very careful study of the portion of the coast between Calais and the Belgian frontier,[1] the depths have not varied much during the present century, the sandbanks having remained tolerably stable, though tending to lengthen out towards the east, whilst the deeper parts of the sea are gradually becoming shallower. It may be inferred that the sandbanks in rising have gradually reduced the section of the inshore channels, till the currents have acquired sufficient velocity to maintain them; and the further raising of the sandbanks has been stopped by the constant disturbance produced by the waves in the shoal water, so that deposit is limited to the still water under the shelter of the banks on their eastern side, and to the greater depths which are unaffected by the waves.

When, however, the normal flow of the inshore currents is at all interfered with, by the construction of any work projecting from the coast, deposit of sand, previously held in suspension by the littoral currents, immediately takes place, and continues till by the alteration of the shore-line another state of equilibrium is attained. When a sandbank exists at a short distance from the coast, with a channel between it and the shore, the channel is maintained by the flow of the currents. Directly, however, the current is checked by the construction of a jetty across the channel, some of the sand borne along by the current is deposited in the channel; also, the pressure of the flowing current against the side of the sandbank being reduced, the bank gradually settles down into the channel, which is accordingly filled up, and a rapid advance of the foreshore ensues.

As the sand-bearing flood-tide preponderates along the southern shore of the North Sea, all the harbours on that coast are more or less subject to the influences described, which have an important bearing on their past and present condition.

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[1] Annales des Ponts et Chaussées. 4th Series, vol. v., p. 137.

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Calais Harbour (Plate 1, Figs. 1, 2, 3 and 4).

The harbour at Calais was originally formed by a lagoon, or natural broad creek, running parallel to the coast, which served as a receptacle for the tidal waters; and the narrow entrance connecting it with the sea was maintained by the discharge of the inland waters flowing into the creek, and by the ebb and flow of the tide. This site appears to have been first used as a harbour in the tenth century, and in the thirteenth century it became the port of communication with England. A long jetty was constructed in the fifteenth century along the top of a sandbank, parallel to the shore, as far as Fort Risban, to afford additional protection to the harbour; and a short jetty was made, starting from the opposite side of the creek, at right angles to the shore, stretching towards Fort Risban. The entrance to the harbour was between Fort Risban and the end of the short jetty. Portions of the creek were from time to time reclaimed by embankments, and by the erection of fortifications, reducing the tidal scour. The long jetty, moreover, promoted the extension of the sandbank on which it was placed. Accordingly the shore line advanced, so that at the beginning of the eighteenth century low-water mark extended about 500 feet in front of the entrance. The jetties were then prolonged, parallel to one another, in a north-westerly direction, in order to obtain a greater depth of water in the entrance channel, according to the scheme proposed by Vauban in 1673, but without the sluicing arrangements which had been included in his plan of improvement. The prolongation of the jetties, however, occasioned an advance of low-water mark to the extent of 820 feet. The existing means of sluicing were, moreover, neglected; and the natural lagoon, which formed a tidal reservoir, was reclaimed by the adjacent proprietors, so that this source of natural tidal scour was lost. The harbour entrance consequently deteriorated. An attempt was made in 1821-2 to improve the entrance again by prolonging the jetties to a total length of 980 yards, so as to make a channel across a sandbank in front. Between 1838 and 1842 a sluicing basin, 140 acres in area, was formed on the side of the old harbour, and the jetties were lengthened 270 yards; but the extension of the jetties was followed, as previously, by a progression of the foreshore. Accordingly when, in 1845, a further extension of the jetties was suggested, the proposition was rejected, as it had become manifest that this means of improvement afforded only a very temporary relief, and led to a rapid advance of the shore line (Plate 1, Fig. 2).

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A large sluicing-basin is being formed at the present time on the low ground near the shore to the east of the entrance channel: it will be connected with the channel by a cut crossing the eastern jetty, whose line will be suitably modified to direct the discharge from the sluicing-basin along the channel. The new basin is much nearer the entrance than the existing sluicing reservoirs, so that, besides largely increasing the amount of tidal water that can be discharged for scouring the channel, the efficiency of the additional volume will be considerably greater (Plate 1, Fig. 2).

The eastern jetty consists of a wide mound, protected by pitching, with a timber superstructure erected on the edge of the inner slope of the mound (Plate 1, Fig. 4); and the inner portion of the western jetty is formed by a masonry pier, up to about half-tide level, surmounted by an open jetty of timberwork (Plate 1, Fig. 3).

Calais harbour possessed a good entrance, with a wide channel between the Brasseux bank and the land, so long as its primitive condition was not interfered with. The long jetty from the shore to Fort Risban, parallel to the coast, whilst advantageous for protecting the harbour, favoured by its shelter the extension of the sandbank on which it was situated, but did not very materially affect the condition of the harbour. As soon, however, as encroachments were made on the tidal area of the harbour, the entrance rapidly deteriorated; and the extent to which the reclamations have been carried is shown by the fact that, whereas at the beginning of the sixteenth century the tidal area within the harbour was from 1,100 to 1,200 acres, and 1,300,000,000 cubic yards of tidal water flowed in and out, the area now amounts to only 30 acres, with a flow in and out of only between 250,000 and 400,000 cubic yards of water.

The attempt to remedy the silting up at the entrance, and to procure a deeper channel by extending the jetties, has been invariably followed by the result, described at the commencement, of an advance of the foreshore in proportion as the jetties were prolonged.

As Calais is situated near the narrowest part of the channel, there is not the same tendency towards the formation of sandbanks in front of it that occurs further to the east. Accordingly though the low-water mark extends to the ends of the jetties, it has no tendency to project further out; and the existing methods of maintaining the entrance channel are sufficient to keep open a deep enough channel to admit the small class of mail steamers which have hitherto run between Dover and Calais at all times of tide; and there is reason to hope that when the new sluicing reservoir is opened, a deep enough channel may be maintained to allow of an improved mail service.

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Gravelines Harbour (Plate 1, Fig. 1).

The harbour of Gravelines is situated to the east of Calais, at the mouth of the river Aa. The existing outlet of the river was formed in the reign of Louis XV. to improve the entrance to the port. Owing to the widening of the North Sea opposite Gravelines, the coast there is more impeded with sandbanks than opposite Calais; the slope of the shore is flatter, and the greater depths recede further from the land. In former times the entrance channel was maintained by the tidal ebb and flow, and by the floods of the valley of the Aa; but since the reclamation of the lands which formed the estuary of that river, sluices have been constructed to provide a more efficient scour at low water. The entrance channel is enclosed between parallel jetties of rubble stone carried out at right angles to the shore; but only small portions were originally raised above high-tide level, so that the littoral currents might be impeded as little as possible. The beach, however, gradually rose against the back of the jetties, and threatened to fill the channel with sand, so that it was found necessary, in 1867, to raise the greater portion of the jetties above high-water level. An open wooden superstructure was placed on the top of the solid portion on each side, at the same time, to assist the entrance of vessels.

The discharge of the river Aa is now barely able to maintain the channel in flood time, so that sluicing has almost always to be resorted to. The sluicing reservoirs, formed out of the old trenches round the town, are much further from the entrance than at Calais. Though the jetties have been made longer than at Calais, they do not even reach low-water mark, owing to the smaller efficiency of the scouring arrangements and the more unfavourable position of the harbour (Plate 1, Fig. 1).

Dunkirk Harbour (Plate 1, Figs. 1 and 5 to 9).

It will be observed that in going further to the east along the French coast the sandbanks increase in number and size, as they do along the English coast after rounding the Foreland and coming opposite Sandwich (Plate 1, Fig. 1). They appear to reach their maximum opposite Dunkirk, and the chart of the coast seems to indicate that the maintenance of a harbour would be attended with greater difficulty there than elsewhere along the coast. The history of Dunkirk harbour fully confirms this view.

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The existence of Dunkirk as a port dates back to the tenth century. Various attempts were made from time to time to improve the entrance channel; but the detailed history of it given by Mr. Dumas-Vence[1] shows how, besides having to contend against the natural difficulties of the site, the harbour was frequently injured by enemies. On several occasions the works of improvement were destroyed, and the entire closing of the port enforced. Reclamations also within the tidal area of the harbour hastened the progress of the deterioration of the channel.

The methods of improvement followed at Dunkirk have been the same as those adopted at Calais and at Gravelines; namely, confining the entrance channel between parallel jetties, extended from time to time out from the shore, and scouring it from tidal reservoirs. As in the instances already described, every extension of the jetties produced a corresponding advance of the foreshore, so that sand-banks, previously existing in front of the entrance, with deep water channels between them and the shore, have been gradually united to the land.

The Dunkirk jetties, about 2,500 feet in length, furnish a most remarkable instance of the extent to which the system of confining a channel between parallel piers, in the endeavour to obtain a deep-water entrance, can be carried (Plate 1, Figs. 5 and 6). Moreover, this extraordinary extension has not achieved the desired result. At low-water spring-tides the sandy shore emerges straight in front of the west jetty, and the low-water line can be seen for some distance to the west extending further out than the ends of the jetties. The shore has also advanced on the east side of the jetties, but not to the same extent, as low-water mark only just reaches out to the head of the east jetty, which, moreover, is somewhat shorter than the west jetty. As the extension of the jetties was found to produce no permanent beneficial results, they have not been lengthened since about 1840, though the western shore shows a tendency to creep round the western pier-head and threatens the maintenance of the outlet. A movable extension, however, has been devised for the eastern jetty, in the form of a timber boom, which is pushed out when the sluices are opened, and compels the current to follow a straight course instead of diverging to the east on passing the head of the eastern jetty; and thus the scouring effect on the channel is prolonged beyond the pier-heads.

Tidal reservoirs were first made out of the trenches of the old

[1] "Notice sur les ports de la Manche et de la mer du Nord." M. Dumas-Vence

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fortifications, and more recently a large sluicing basin was constructed on the western side of the entrance channel in front of the town.

Till the year 1877 the entrance channel was maintained solely by sluicing; but though the scouring current sufficed to keep the channel between the jetties clear of silt to a depth of from 5 feet to 8¼ feet below the lowest spring tides, it lost most of its efficiency soon after passing the pier-heads, beyond which the depth decreased to 1 foot 6 inches at the shallowest place, deepening again further on towards the Dunkirk roads.

M. Eyriaud-des-Vergnes, the engineer-in-chief at Dunkirk Harbour, considers that sluicing is positively injurious to the navigable channel beyond the jetties, in such a situation as Dunkirk, on account of the set of the tides at that part of the coast. In his opinion, the silt removed by the sluicing current during the latter part of the ebb is carried westwards, where in fine weather it is deposited, increasing and consolidating the foreshore, or in rough weather it is held in suspension and is brought back by the flood.

The port of Dunkirk is in a flourishing condition, owing to its possessing a safe roadstead, and on account of its providing convenient access by railways and canals to a thriving district. An improved entrance channel was urgently needed to meet the increasing requirements of its rapidly-growing trade. Dredging has consequently been resorted to for deepening the channel beyond the jetties; and, as is usual in this method of improvement, the amount thus removed has been increased from year to year. Thus whilst in 1876 the quantity of material removed by dredging was only 11,742 cubic yards, it amounted to 53,937 cubic yards in 1877, it was 90,545 cubic yards in 1878, 111,858 cubic yards in 1879, 202,622 cubic yards in 1880, and by the end of September 1881 had already reached 247,975 cubic yards, and was expected to amount to 314,000 cubic yards by the end of the year. The whole of the dredging operations outside the jetties are performed by means of rotatory pumps fixed on hopper barges; and additional particulars relating to them are given in Appendix I.

Since the spring of 1881 three dredgers have been employed at Dunkirk, with the object, in addition to deepening the channel, of excavating a sort of reservoir to the west of the channel in which sand, brought along by the flood tide, may settle before reaching the navigable channel. This arrangement enables the dredgers to perform a portion of the work of maintenance out of the way of

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vessels entering or leaving the harbour. It, however, appears open to the objection of increasing the amount of sand required to be raised, as every depression of the foreshore below the natural level favours the deposit of sand.

The results effected by the dredging operations are shown by a comparison of the lines of soundings outside the pier-heads in 1876 and 1881 respectively, kindly furnished by Mr. Eyriaud-des-Vergnes, from which the Author has made three sections to illustrate the change (Plate 1, Figs. 7, 8, and 9).

The jetty channel is much longer than would be necessary for attaining the same distance from the shore, owing to its direction being inclined at an angle of about 50° to the coast line, instead of at right angles to it. The Author thinks that the original choice of this direction was due to the fact that the channel to the port was at right angles to the line of an inshore channel which existed, and served as an outlet, before an out-lying sandbank was joined to the mainland; and the jetties have been subsequently extended in the same line. The jetty channel (230 feet wide) is also too narrow to allow two of the larger class of vessels to pass easily when the tidal current is strong.

Accordingly the construction of a shorter and wider channel, pointing straight out to sea, is at present under consideration.

Large dock and quay works are in course of construction at Dunkirk for accommodating the rapidly-increasing trade of the port. Some of the works are being carried out on the site of the large sluicing basin; but they have been so designed that the same volume of water will be available for sluicing as formerly, without reducing the depth of the water in the new docks below 23½ feet (Plate 1, Fig. 5).

The growth of the trade of the port of late years is well indicated by the statistics in Appendix II., the total yearly tonnage of vessels and of goods entering and leaving the port having been trebled in the last twenty years. This result must be attributed to the natural prosperity of the port, and, within the last five years, to the deepening of the entrance channel, and not to the new works, as the first section of these works, consisting of the Freycinet Dock, having a length of quays of 1,800 feet, was only completed and opened for traffic towards the end of 1880. The advantage gained from the deepened entrance channel is specially manifested by the rise in the average tonnage of the vessels frequenting the port, for whereas this average was 174 tons in 1870, it had risen to 286 tons in 1880, amounting to an increase of 64 per cent.

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Nieuport Harbour (Plate 1, Figs. 1 and 10).

Travelling along the coast from Dunkirk towards the east, and crossing the French frontier, the next harbour reached, situated on Belgian territory, is Nieuport. Looking at the chart of the coast (Plate 1, Fig. 1), it appears that the flood tide, passing through the Straits of Dover, having deposited a large proportion of the material which it held in suspension before reaching Nieuport, exhibits less tendency to form sandbanks as it passes further to the east. Thus the coast in front of Nieuport is less encumbered with sandbanks than opposite Dunkirk, and a continued improvement in this respect is manifested on proceeding still further towards the north-east.

The river Yser, of which the Nieuport channel forms the outlet, formerly flowed into a creek which admitted the tide up to Dixmude, and even further inland. Lombartzyde, the ancient port of that part of the coast, was destroyed by the sea during a storm in 1115, and its entrance channel was filled up with sand; and the inhabitants shifted to Nieuport, situated at another point on the creek (Plate 1, Fig. 10).

Dikes were constructed by degrees to protect the coast from the ravages of the sea, and to reclaim land, occasioning a gradual silting up of the creek, of which, with the exception of the bed of the Yser, not a vestige remains. In 1643 the waters of the Yser were retained by sluice-gates and discharged at low tide, so as to scour the entrance channel which was gradually deteriorating. Other sluices have been erected since then, close to the town of Nieuport, with the object of employing the water draining from the adjacent country, through the various channels which unite there, for scouring the channel of the Yser, which forms the approach to the port.

Nieuport is now about 2 miles distant from the sea. The river between Nieuport and the sea was embanked during the last century, and several groynes of timberwork, and of fascinage pitched with brickwork, were placed in front, and at right angles to the embankments, on each side, for the purpose of protecting them. These groynes, however, have injured the navigable channel, as they intensify its tortuous course near the town, and produce irregularities in its section. The lower portion of the river channel is regulated by parallel jetties, which follow a tolerably straight course from the ends of the embankments to the sea (Plate 1, Fig. 10). The jetties are formed of timber, but behind the eastern jetty there is a low solid mound pitched with brickwork, rising

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2 or 3 feet above the level of the sandy beach, to prevent the sand from falling into the entrance channel. A similar mound is being constructed behind the western jetty. This jetty extends a little distance beyond the other, and, bending slightly towards the west near its extremity, enlarges a little the width of the entrance. Low-water mark extends out as far as the ends of the jetties, and has evidently advanced in consequence of their construction. Further inshore, the sand, blowing from the west along the shore, which has been prevented from passing through the western jetty by boards fastened against its outer side up to the footway, has heaped up against the jetty till it has reached the level of the footway on the top, and is blown over it into the channel. The depth at the entrance at low water is only a few inches. A bank of sand exists almost all along the inner side of the west jetty, and blocks up half the channel in places at low water. The channel is in its best state after the winter floods, coming down from the river and the drainage canals, have scoured it. Owing probably to the comparatively small importance of the port, no tidal sluicing basins have been formed to assist in maintaining the channel, and dredging has been very little employed.

Ostend Harbour (Plate 1, Fig. 1, and Plate 2, Fig. 1).

The next harbour to Nieuport along the Belgian coast is Ostend, the second port in the kingdom (Plate 1, Fig. 1). Though the Stroombank is situated nearer the entrance to the port than the Nieuport bank to the entrance to Nieuport harbour, Ostend is more favourably situated than Nieuport in other respects. The sandbanks are less numerous in front of Ostend, and the sea has a tendency to encroach upon the beach instead of receding as at Nieuport, owing probably to the coast line projecting somewhat at Ostend, whilst it is slightly embayed at Nieuport.

The town of Ostend, which is situated on a low marshy district, was protected in early times from the sea by two dikes, the second dike having been made to afford additional security, as the first was frequently breached by the sea. In the year 1445 permission was granted to make a navigable channel to the west of the town, across the outer dike and up to the inner one and close to the town. As this channel tended to silt up, a sluice was erected at the upper end of the channel, through which water was admitted into interior channels and ditches at high water, and discharged at low water. This channel having gradually deteriorated was eventually abandoned, about the year 1571, when the existing channel

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to the north-east of the town was constructed, through a breach which the sea had made in the dike. Through this breach the sea had access to a tract of low-lying land, 7,400 acres in extent, round which embankments had been made which were joined to the dunes on the sea coast. In 1628 a new embankment was formed reclaiming 3,000 acres from this area. The harbour at once began to silt up in consequence of having lost a large proportion of its scouring reservoir, owing both to the area shut off by the embankment and the raising of the remainder by the deposit of silt introduced at every tide. Accordingly, in 1662, one of the embankments was cut through, and the tide re-admitted to a portion of the reclaimed lands, which afforded such a scour that not only was the harbour restored to an excellent condition, but fears were entertained that the increased current would injure the town and undermine the jetties alongside the channel. The alarm raised on this account, and the entreaties of the landowners to have the inundated land restored to them, led to the closing again of the embankment in 1700. The harbour in consequence was again invaded by sand, and the channel was so nearly closed up in 1730 that another embankment was cut through, and the tide admitted into the lowest of the polders. This expedient did not prove so efficient as on the former occasion, for the land over which the tide flowed had been gradually raised by the constant deposit of silt. Accordingly a portion of the submerged area was again reclaimed, in 1744, as having become useless for the purpose of scour; and at length this method of scouring the entrance channel had to be abandoned. The submerged lands were consequently all reclaimed at last. No works of importance were executed between 1730 and the close of the century; but as the adjacent marsh lands became raised and were reclaimed, the entrance deteriorated.

Early in the present century the parallel jetties for guiding the channel to the sea were prolonged; and the first sluicing basin was opened in 1810, and another in 1821. A new west jetty was constructed in 1833–7, parallel to the eastern one, and at only just sufficient distance from it to provide a suitable channel for navigation, as the previous channel had proved to be too wide to be properly maintained; the eastern jetty was prolonged at the same time. By these improvements a depth was obtained, in 1841, of 5 feet 9 inches at low water over the bar at the mouth, and 11½ feet inside the harbour. In 1851 further improvements were commenced. The two sluicing basins were connected; the west jetty was completed by a low stone jetty, and a new sluicing

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basin nearer the sea, on the eastern side of the entrance channel, was constructed. This basin has its outlet where the entrance channel makes a bend towards the west, so that it points exactly in the line of the outer portion of the channel, and thus the issuing current from the new basin is directed so straight along the channel as to attain the utmost measure of efficiency (Plate 2, Fig. 1). The new scouring basin and sluices were completed in 1863, and, acting together with the original sluices, produced a depth of 7 feet 10 inches over the bar at low water. These works placed the harbour in its present condition, and dredging is now being resorted to for increasing the depth over the bar at the entrance. The jetties are similar in construction to those previously described; they consist of open timberwork next to the channel, and a low mound, pitched with brick or stone, at the back slightly raised above the existing level of the beach, and following its slope towards the sea.

Though the form of the jetties in the several harbours described varies somewhat, the objects aimed at are the same in all, namely, to keep the sand on each side from falling into the entrance channel, and to concentrate the ebbing tide. These objects are effected by the low solid portions; whilst the open timberwork marks the channel, furnishes a roadway to the pier-heads, and serves for warping and guiding the vessels without presenting any great obstruction to the flow of the littoral currents.

Blankenberghe Harbour (Plate 1, Fig. 1).—Between Ostend and the mouth of the Scheldt there exists the small harbour of Blankenberghe, which is somewhat similar to the harbours already described, having an entrance channel across the beach maintained by the tidal scour of two basins. It is, however, a harbour of very little importance, and possesses no water communication with the interior. The coast, however, opposite Blankenberghe, is freer from sandbanks than at Ostend, and accordingly a spot has been selected a short distance east of Blankenberghe, where deep water approaches nearer to the shore, for a proposed new harbour, somewhat similar in design to Ymuiden harbour, which, by means of a canal, might give Bruges an improved access to the sea (Plate 1, Fig. 1).

The Jetty Harbour System.

All these harbours along the southern shore of the North Sea, which may be termed jetty harbours, present a remarkable similarity both in their early history and in the methods adopted for their improvement and maintenance. The first period of their history

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consisted in the establishment of a small harbour, owing to favourable local conditions, such as the mouth of a small river or creek. Then, as the trade developed and the value of land increased, reclamations were made from the tidal area inside the harbour which had served as a scouring reservoir, and the harbour entrance consequently deteriorated. The next stage was the improvement of the entrance channel by confining it between parallel jetties which concentrated the tidal scour and improved the depth. Experience having proved the great value of tidal scour, all ditches and remaining reservoirs of tidal water were carefully maintained, their depth increased, and sluices constructed, so that the whole volume of tidal and fresh water held back might be discharged at low tide, when its scouring efficiency would be the greatest. When a greater depth was required, or the entrance channel began to silt up, the jetties were prolonged; but, owing to the littoral drift, the shore line advanced with every extension of the jetties, till at last any further extension was opposed as at Calais, or made only temporary as at Dunkirk. As, however, fresh measures were needed to maintain the depth of the entrance channel, and even to increase it in order to provide for the increasing draught of vessels, artificial tidal sluicing-basins were constructed; and finally dredging has been partially resorted to as a means of deepening the channel. Though the range of tide decreases gradually from 20 feet 6 inches at Calais to 14 feet 4 inches at Blankenberghe, and the scouring power must be proportional to the rise, other influences, such as the amount of deposit, the position of the sandbanks, the length of the channel, and the reservoir area, vary so much at the different ports, that the effect of the difference in the rise of tide is not clearly marked.

Comparison between Jetty and other Harbours.

Turning to the English coast, there are scarcely any instances of harbours strictly comparable with those under consideration. Sandwich, one of the Cinque Ports, which occupied a somewhat analogous position, was allowed to fall into decay, and the shore in front of it has advanced considerably from purely natural causes. Though the harbours of Rye and Newhaven are jetty harbours, they are exposed to the drift of shingle and not of sand: the former harbour has been greatly neglected, and its tidal reservoir area has been much reduced; and the latter harbour exhibits the same difficulties in maintenance that have attended the harbours in the North Sea. Perhaps the nearest parallel instance is Lowestoft harbour. Here a jetty harbour was constructed, with Lake Lothing for its scouring

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reservoir; but it proved less successful than any of the harbours described. The channel between the jetties was soon filled up with sand, owing to the inadequacy of the scouring reservoir and the littoral drift of sand from the north. In this case the jetties were not extended as on the Continent, but were enclosed between two solid breakwaters placed further apart, extending into deeper water, and converging at the outer end, so as to leave a small opening pointing toward the south-east, away from the drift and prevalent wind. This plan, however, has not been very successful, as the foreshore has progressed considerably on the northern side, and low-water mark extends in front of a part of the eastern arm of the northern breakwater; the depth at the entrance has decreased considerably, and a large quantity of sand has accumulated inside the harbour. A jetty has recently been projected from the northern breakwater by Mr. Langley, M. Inst. C.E., to arrest the travel of the sand from the north; and dredging, by means of sand pumps, is being regularly carried on to maintain the entrance.

There are instances of harbours in Great Britain and Ireland, at the mouths of small rivers opening on to a sandy coast, where the jetty system has been adopted; but the endeavour in these cases has been to promote tidal scour, and to render the natural discharge more efficient by improving the river above, instead of placing sluices across the river and making artificial tidal reservoirs. Thus jetties were erected, on each side, at the mouth of the Wear for improving the port of Sunderland,[1] at the mouth of the Dee for Aberdeen harbour, and at the mouth of the Yare for Yarmouth haven. The jetties, however, have not been prolonged at Sunderland and Yarmouth like the continental jetties. The new breakwaters at Aberdeen, the piers at Tynemouth (Plate 3, Fig. 9), and the south and north walls at the mouth of the Liffey,[2] whilst resembling the jetty system in carrying the entrance into deeper water, differ from it in supplying their own tidal reservoirs by being placed some distance apart at the shore, in such a manner that, whilst converging towards their extremities so as to concentrate the scour at the entrance, they enclose a large tidal area. They also differ from the continental system in the piers being made solid, instead of open above; though at Dublin, owing to the peculiar set of the tidal currents, the outer portion of the north wall was not raised above half-tide level. The object, however, attained at

[1] Minutes of Proceedings Inst. C.E., vol. vi., plate 30.
[2] *Ibid.*, vol. lviii., plate 1, fig. 5.

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Aberdeen, Tynemouth, and Dublin, of carrying the harbour entrance into deep water could not have been accomplished at Dunkirk or Ostend, in consequence of the flatness of the shore and the sandbanks in front, which preclude all possibility of reaching deep water.

Judging from the past history of the jetty harbours in the North Sea, it would appear that if, instead of extending the jetties, reclamation within the tidal area had been prevented, and scouring reservoirs had been formed at an earlier period, the maintenance of these harbours at the present day would be both easier and cheaper. The long entrance channels, whilst failing to reach deep water, are prejudicial to scouring efficiency. It is possible that the plan of rapidly converging piers, adopted at the south entrance to the port of Sunderland, would have been more successful, as a tidal reservoir would be thus formed close to the entrance; nevertheless the value of sluicing reservoirs well placed and opened at low water is considerable. Probably a combination of these two methods of scouring the entrance, as attained at Sunderland by means of the dock sluices, would have been most likely to prove satisfactory in such a very unfavourable situation as Dunkirk. The scouring current indeed loses its force on emerging from between the pier heads, and a bar tends to form in front of the entrance, but it may be periodically removed by dredging if the current across the ends of the jetties does not act upon it. The entrance channel may also be greatly improved by dredging if the prosperity of the port admits of the adoption of this course, as in the case of Dunkirk harbour. The cost, however, of maintenance is largely increased by this method of improvement; and every additional increase in depth thus attained increases in a sort of geometrical ratio the amount of material that has to be removed every year in order to maintain it.

Boulogne Harbour (Plate 2, Figs. 2 to 6).

An interesting example of the conversion of a jetty harbour into a large closed harbour is now being carried out at Boulogne. The new harbour works were commenced in 1879 (Plate 2, Figs. 2 to 6). A breakwater is being constructed out from the shore, starting from the land at a distance of 1¼ mile to the south-west of the existing jetties. This breakwater is to be carried straight out for a length of about 4,600 feet, and then, making a bend, it is to be prolonged in a northerly direction, at an angle of 60° to its former course, for a length of about 2,300 feet, in a depth of from 23 to 26 feet at low water. An opening will be

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left at this point 820 feet wide, beyond which a detached breakwater will be built, following the same line as the outer arm of the south-western breakwater, and having a length of 1,640 feet. Another opening 490 feet in width will be left between the northern extremity of the detached breakwater and the outer end of the north-eastern breakwater, which is to be built out to a distance of about 4,600 feet from the shore in prolongation of the existing eastern jetty of the present entrance channel to the port. Particulars about the present state of these works, and about the proposed quay works inside the harbour, are given in Appendix III.

As Boulogne Harbour is situated to the west of the Straits of Dover, it is out of the influences affecting the jetty harbours to the east of the Straits; and the sea in front of Boulogne is tolerably free from sandbanks. Accordingly, although Messrs. Stœcklin and Laroche, the engineers who designed the harbour, anticipate that some progression of the foreshore will follow the construction of the sheltering breakwaters, the rate of progression is likely to be slow; and; as the entrance will extend into a depth of 4 fathoms at low water, the accumulation of sand inside, driven in by waves, will not be considerable.[1] The new harbour at Boulogne will therefore resemble Ymuiden and Madras harbours in having a good depth at the entrance, and a comparative freedom from sand-bearing waves, together with the additionable advantage of a greater rise of tide and consequently a stronger scouring current at the entrance. Messrs. Stœcklin and Laroche indeed, judging from the scour round Cape Alprech, expect that the prominent position of the outer face of the harbour, with regard to the adjacent coast line, will occasion a scour in front, which they anticipate will keep the entrance free from any bar.

Madras Harbour (Plate 2, Figs. 7 and 8.)

An instance of a harbour situated on a sandy coast, and enclosed by solid piers, is furnished by Madras Harbour, which was approaching completion previous to the cyclone of the 12th of November, 1881, when portions of the outer piers were damaged. It was designed by Mr. W. Parkes, M. Inst. C.E., and is intended to protect vessels from the high and dangerous surf which breaks on the straight sandy beach in front of Madras. The harbour is sheltered by two breakwaters which extend out at right angles to the shore at a distance of 3,000 feet apart. These breakwaters both stretch

[1] "Des ports maritimes." Report by Messrs. Stœcklin and Laroche, 1878.

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out seawards, parallel to one another, for a length of about 3,000 feet from the shore, and then curving round they converge with return arms inclined at an angle of 70° to their original direction. An opening of 550 feet is left between the pier-heads for the entrance to the harbour (Plate 2, Fig. 7). The harbour is symmetrical in form, and nearly square, and has an area of about 220 acres. A cross section indicates the construction of the breakwaters (Plate 2, Fig. 8). As the entrance is situated in a depth of water of 45 feet, the harbour may be considered to be secure from silting up by sand brought in by waves through the entrance, as waves do not stir up the bottom at that depth. Fears, however, were entertained at the outset that the solid southern breakwater would act as a groyne, and, arresting the sand drifting northwards along the coast during the prevalence of the south-west monsoon, would cause a rapid advance of the foreshore. When the piers had advanced only a short distance from the shore, the sand, drifting along from the south, not only heaped up against the southern pier, but was actually carried round the end of the pier into the sheltered area between the piers, and produced an advance of the shore. This action, however, ceased when the southern pier reached fairly deep water. It was natural, however, to suppose that the sand, being prevented from entering the harbour by the advance of the southern pier, would accumulate in the angle between the pier and the shore. An accumulation of sand does indeed take place each year during the continuance of the south-west monsoon; but a considerable portion of the sand thus brought in is carried away again by the sea during the period of the north-east monsoon, so that the actual yearly progression of the shore to the south of the harbour is comparatively small (Plate 2, Fig. 7). Moreover the advance, though quite apparent, is becoming less as deeper water is reached. Some sand finds its way into the harbour through the interstices between the blocks of the south pier, but it settles close to the inner face of the breakwater, and can be easily removed by dredging when necessary. Slight changes have occurred in the depths inside the harbour; thus the depth has slightly decreased between the 5-fathom line and the shore, whilst a corresponding accumulation of sand has taken place on the shore. This result may be attributed to the action of the waves entering the harbour. The range of tide at Madras is only 3 feet.

The experience gained at Ymuiden, Port Said, Madras, Kurrachee, and other harbours, tends to show that a considerable littoral drift of sand is not an insuperable obstacle to the effective maintenance

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of a harbour with solid piers on a sandy beach. There is undoubted evidence at Ymuiden of an advance of the foreshore on the outer sides of both the piers, as at other places on the North Sea coast;[1] the advance of the shore against the western side of the west jetty at Port Said (Plate 2, Figs. 9 and 10) was for some time viewed with alarm; the extension of the beach on the south side of Madras harbour during the south-west monsoon (Plate 2, Fig. 7) was a cause of considerable anxiety at the outset; and the Manora breakwater at Kurrachee[2] was constructed with the special object of arresting the sand drifting across the harbour mouth. Though sufficient time has not elapsed since the completion of Ymuiden harbour to allow of an estimate being formed of the probable rate of the progression of the shore, it is certain that it will become considerably less as deeper water is reached. At Port Said, according to the recent reports of Sir F. de Lesseps, the western shore has attained a state of equilibrium. At Madras a gradual accumulation of sand on the south side of the harbour is anticipated by Mr. Parkes, though at a constantly decreasing rate; and as the breakwaters extend into a depth of 45 feet at low water, the sand is certain not to encumber the entrance for a long period: and at Kurrachee the rapidly shelving shore is peculiarly favourable to the maintenance of the entrance channel.

If Boulogne and Madras harbours and the other similar harbours recently constructed fulfil the expectations formed of them, they will afford valuable evidence of the conditions under which closed harbours on sandy coasts can be maintained without difficulty, of which Kingstown harbour furnished formerly the only satisfactory example. The danger to these harbours, as well as to jetty harbours, consists in the progression of the foreshore, as tidal scour and dredging are capable of coping with the accumulations inside.

ESTUARIES.

(Plate 3.)

In the case of the harbours alluded to above, the general designs exhibit some similarity, notwithstanding great differences in the range of tide. Thus the plan of the harbour at Boulogne, with a rise of tide of 25 feet, is very similar to that of Madras, with a rise of only 3 feet; and the principles of design adopted at Kingstown harbour, with a rise of 11 feet 3 inches, resemble those at Ymuiden, where

[1] Minutes of Proceedings Inst. C.E., vol. lxii., plate 1, fig. 9.
[2] *Ibid.*, vol. xliii., plate 1.

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the rise of tide is only 6 feet. The object to be attained being a sheltered area and a good depth at the entrance, a deficiency in tidal scour has to be compensated for by dredging as at Port Said, or by a deep entrance as at Madras. The improvement, however, of the mouths of large rivers has to be conducted under different conditions. Here the depth at the outlet has to be maintained by tidal scour and the discharge of the fresh waters; or, in the case of rivers flowing into non-tidal seas, by the fresh waters alone. The river-discharge is a definite volume of water which has to escape, whatever the width provided at the mouth; and if no tidal influences exist, the narrower the width at the outlet the deeper is the channel. If, however, the river flows into a tidal sea, and its estuary is large, even a small fluctuation of tide has far more influence on the maintenance of the estuary than the inland waters. There can be no doubt that the maintenance of the estuaries of the Thames, the Severn, the Humber, the Mersey, the Scheldt, and many other rivers, is due mainly to the tidal ebb and flow, aided in some measure by the fresh-water discharge, and that if the tidal influence were removed the rivers would be inadequate to maintain such large channels in opposition to the heaping-up action of the sea along the coast. Accordingly, when any portion of the estuary of a tidal river is cut off the amount of tidal water flowing in and out is reduced, which is liable to affect the maintenance of the estuary. If indeed an estuary is very irregular in width, and has indents, it may be regulated with advantage, as under those circumstances a reduction of the tidal volume is compensated for by the enforcement and concentration of the tidal currents; but a great reduction of the estuary channel infallibly leads to a deterioration of the outlet.

Thus the principles regulating the improvement of non-tidal rivers along one of the shallow channels of their deltas, and the establishment of a deeper channel across the bar at the mouth of a tidal river, are essentially different. The contraction of the channel between jetties at the Sulina mouth of the Danube, and at the South Pass of the Mississippi, has enabled the discharge of these rivers to scour out a deeper channel at their outlets. Moreover, the current running across the ends of the Sulina piers in the Black Sea, and either the increased velocity of the current in the South Pass carrying the alluvium of the Mississippi into deep water, or a cross current at the ends of the South Pass jetties, have prevented hitherto the formation of a bar further out at the mouths of these rivers.

Mouth of the Adour (Plate 3, Fig. 5).—A somewhat similar

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method of improvement was adopted at the mouth of the river Adour some years ago, where the tidal rise is only 8 feet 2 inches. In order to obtain a deeper channel across the bar, raised at the mouth of the Adour by north-westerly storms, the outlet channel was guided and contracted by rubble mounds across the beach, so that the water discharged by the river might be concentrated on the bar; but whilst the depth over the bar was only slightly improved, the tidal range at Bayonne was reduced (Plate 3, Fig. 5). The jetties were prolonged in the year 1859 by open timberwork trestles, which were replaced, in 1867, by iron cylinders with movable panels sliding into the intermediate spaces, making the jetties close or open as desired, so that whilst directing the current they might offer as little impediment as possible to the littoral drift. The bar was by this means lowered about 3¼ feet, but it still exists beyond the ends of the jetties, and the foreshore has advanced. The reduction of tidal range at Bayonne, the port for which the Adour was improved, and the loss of tidal volume, are defects resulting from the works, which might have been avoided by not treating the Adour as a non-tidal river, but by keeping the width between the jetties the same as that of the river above.

The estuaries of the Seine and the Meuse, opening on to sandy coasts, have been regulated within recent years; and the effects produced by the works are still in progress. As short descriptions of the works of improvement on these rivers have been given in the Selected Papers and in the Abstracts in the Minutes of Proceedings,[1] the Author need only refer here to such portions of the works as may be necessary for a proper explanation of the changes effected.

The Tidal Seine Embankments (Plate 3, Figs. 1, 2, 3 and 4).

The object of the works on the tidal portion of the Seine was to improve the shallow, shifting and winding low-water course of the river in the estuary, below La Mailleraye, so as to render the navigation channel to Rouen both deeper and less dangerous. The works consisted in confining the river between embankments from La Mailleraye to Berville (Plate 3, Figs. 1, 3 and 4). The width between the embankments was made 980 feet at the commencement, and increased to 1,540 feet at the lower portion. This scheme, proposed by Mr. Bouniceau in 1845,[2] was commenced

[1] Minutes of Proceedings Inst. C.E., vol. xli., p. 166; vol. xlix., p. 348; vol. lii., p. 369; and vol. liv., p. 299.

[2] "Étude sur la navigation des rivières à marées." M. Bouniceau, p. 152.

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in 1848, completed as far as Berville in 1869, and has proved very successful as regards the improvement of the channel within the limits of the embankments (Plate 3, Fig. 2). The embankments have both fixed and deepened the navigation channel, which has been further improved by dredging. The time occupied in the journey to Rouen has been reduced from four days to one or at most two tides; the cost of carriage has been lowered to one half, and the available depth has been increased from 10½ feet to 21 feet.

This result would appear to indicate that a tidal estuary, with a rise of tide of 22 feet at its mouth, may be greatly restricted with advantage to its navigable channel, which is in direct opposition to the view previously expressed as to the value of the tidal waters in maintaining an estuary. There is, however, another most important aspect of the case which is liable to be disregarded. In addition to the improvement of the channel, the portion of the estuary behind the banks has been silting up, and 21,250 acres of land have been reclaimed from the estuary. Mr. Bouniceau foresaw that his scheme would lead to the silting up of the upper estuary behind the banks, and eventually lower down; but he considered that the first effect would be the conveyance of sand from the sandbanks at the mouth of the estuary to the upper portion behind the embankments. Basing his calculations, with regard to the silting up of the estuary, upon the amount of available deposit washed away annually from the adjacent cliffs along the coast, he considered that twenty-one thousand years would elapse before the sandbanks in the lower part of the estuary were raised again to their original level, after furnishing the material for the silting up of the upper part behind the banks. In the original scheme it was proposed to extend, eventually, the banks nearly down to the sea, which is about 9 miles below Berville; and Mr. Bouniceau estimated the total amount of deposit necessary to raise the portions of the estuary behind the banks to the level suitable for reclamation, at 824,000,000 cubic yards. If the estimate of the period required for the accumulation of this quantity of deposit had been correct, it would have proved that the maintenance of the estuary of the Seine was very slightly influenced by the tidal ebb and flow.

It appears, however, from a recent survey of the estuary by Mr. Estignard,[1] that the reduction of the tidal capacity of the estuary of the Seine, since 1834, amounts to 272,000,000 cubic yards; and the Author deduces from the data furnished by

[1] "Reconnaisance Hydrographique à l'embouchure de la Seine." X. Estignard.

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Mr. Estignard that the yearly accumulation of deposit has doubled in the six years between 1869 and 1875. From the results of Mr. Estignard's survey, it appears that of the total amount of silt, for the accumulation of which Mr. Bouniceau allowed two hundred and ten centuries, one-third has already deposited in the estuary, only thirty-three years after the embankments were commenced. Large tracts of land have emerged from the water beyond the embankments, and the silting up of the estuary is proceeding at a rapidly increasing rate. Thus whilst the shifting winding channel between La Mailleraye and Berville has been improved with great advantage to the trade of Rouen, the rapidly changing condition of the estuary, from the diminution of tidal volume, is causing much anxiety for the approach channel to Havre. If the silting up continues at its present rate, the banks, which were stopped at Berville for the sake of not endangering Havre, will soon need extension to preserve the channel between Berville and the sea, and the channel will have to be trained towards Havre to maintain its entrance.

An interesting report by Mr. Vauthier has been recently published treating of the changes which have occurred in the tidal Seine and its estuary, and indicating the further improvements which might be effected in its navigable channel.[1] He proposes that the channel between the embankments should be deepened by dredging at certain shoal places, so that a minimum depth of 24 feet at high-water neap-tides may be obtained between Rouen and the sea. This scheme, resembling the works so successfully carried out on the Tyne, the Clyde, and the Tees, could not fail to improve the condition of the river channel, as it would both introduce a larger volume of tidal water and also facilitate the discharge of the fresh waters. The increased scour, moreover, thus produced, would not only tend to deepen shallow places in the embanked channel, but would also assist in maintaining the channel below the embankments.

The charts of the estuary of the Seine in 1834, 1853, 1866, 1869, and 1875 appended to the report, indicate most forcibly the irregular and shifting character of the navigable channel beyond the ends of the embankments. Mr. Vauthier, however, whilst admitting the correctness of Mr. Estignard's report, as regards the large deposit of silt that has taken place within recent years in the estuary, considers that the estuary has by this time reached a state

[1] "Rapport sur les améliorations dont sont encore susceptibles la Seine maritime et son estuaire." Par L. L. Vauthier, 1881.

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of equilibrium, and that the silting up has all occurred in the eastern part of the estuary, whilst the depths in the western part have improved. It appears indeed from the charts and the longitudinal sections of the outer channel accompanying the report that the outer part of the channel has deepened somewhat to the east since 1834; but a decided bar, reaching nearly up to low water, appears in the channel between Havre and Honfleur on the section of 1875, which did not exist in 1834.

The divergence of opinion between engineers as to the proper widths for an embanked channel receives a fresh illustration from Mr. Vauthier's report: for, whilst the Seine embankments have been carried out in accordance with the lines which Mr. Bouniceau advised,—Mr. Malézieux attributes the shoaling of certain parts of the channel, in the summer, to the banks being placed too far apart,[1]—and Mr. Vauthier, on the contrary, considers that the estuary channel has been made too narrow and impedes the entrance of the tide, which injurious effect will be augmented when the low-water embankments are eventually raised.

Mr. Vauthier proposes to commence an increased widening out of the channel at Tancarville, removing for this purpose the existing northern embankment below that point, and to prolong the embankments to the projecting coast line near Havre on the north, and to Honfleur on the south.

The navigable channel beyond the embankments urgently requires improvement; and the works hitherto carried out furnish an incomplete remedy to the natural defects of the river. The Author agrees with Mr. Vauthier in his views as to the extension and enlargement of the embanked channel; but he would prefer carrying the trumpet-shape of the mouth even farther up the river, if the existing embankments admit such a course. The critical part of the whole channel is that which lies between the meridians of Honfleur and Havre; this is the part which, as might be expected, appears to have been already injured by the reduction of the tidal capacity of the estuary, and it is the part where shoaling may increase in the future if the silting up of the bay continues. The only remedy now is, not to restrict further the tidal capacity of the estuary beyond the extent necessary for regulating the channel; but to add to this capacity, and to concentrate the scour of the ebb, by deepening the channel above. It is possible that, owing to the greatly diminished tidal capacity of the estuary, it may be found impracticable to maintain a stable

[1] "Cours de navigation intérieure." M. Malézieux, p. 204.

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deep-water channel in the wide expanse between Havre and Honfleur; in which case it will be necessary to train a restricted channel towards the sea. In order, however, under these circumstances to provide for both Honfleur and Havre, it would be needful either to form a winding channel approaching both of these ports, or to make a secondary channel connecting Honfleur with the main channel directed towards Havre.

The importance of tidal scour in maintaining the estuary of the Seine has already been clearly manifested by the changes resulting from the reduction of its tidal capacity; and if deep water did not exist in the sea in front of the mouth of the Seine, the maintenance of the outlet of the navigation channel might be liable, before long, to entail considerable trouble and expense.

Works at the Mouth of the Maas (Plate 3, Figs. 6, 7, and 8).

Continual changes have been taking place in the various channels through which the Maas finds its way to the sea. The general tendency is for the north-eastern channels to silt up, and for the south-western channels to become the principal channels, in consequence of reclamations of land and the increased tidal range towards the south. Thus the Scheldt has gradually deserted its eastern branch, and now discharges solely through its western branch; the eastern Scheldt having been barred off, in 1867, by the construction of a railway embankment across it between Bath and Bergen-op-Zoom. In like manner vessels trading with Rotterdam were gradually obliged to desert the more direct channels of the Maas, and approach by the deeper southern outlets.

The Voorne canal, excavated in 1829 to furnish a shorter channel towards Rotterdam, eventually proved too small for the more modern requirements of width and draught.

After a careful consideration of various proposed methods of improvement, it was decided, in 1872, to adopt Mr. Caland's scheme for improving the outlet of the Scheur branch of the Maas by forming a cut through Hoek-van-Holland, with jetties at right angles to the shore, leading the channel into deep water (Plate 3, Fig. 6). The shortest possible route to Rotterdam is thereby obtained; and the required depth of 7 metres at high water approaches nearer the shore at the site selected for the outlet than elsewhere along the adjacent coast, so that shorter jetties suffice. The scheme included the regulation of the river up to Krimpen above Rotterdam, so that it might have a width of 740 feet at Krimpen, increasing to 1,470 feet at Vlaardingen, and 2,950 feet at the extremities of the

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jetties, which may be regarded as extensions of the gradually widening-out banks of the river into deep water, as the jetties are 2,790 feet apart at the shore and 2,950 feet at the ends. The jetties at the mouth of the Maas possess the interest of being almost the first instance of the employment of fascine work in an exposed situation in the open sea (Plate 3, Fig. 7); though recently this system of construction has been used on a still more extensive scale at the South Pass of the Mississippi. Unlike the jetty harbours on the southern shore of the North Sea, the Maas jetties are not surmounted by an open timber superstructure, except for a short distance from the shore along the southern jetty; and, unlike Ymuiden, the outer portions have not been raised above half-tide level, which exposes them less to shocks from waves, and affords a more free entrance to the flood tide, whilst equally well concentrating the scouring portion of the ebb.

A very evident progression of the foreshore has taken place on the outer side of each of the jetties. Although it was arranged at first that the northern jetty should extend further out than the other, in order to protect the entrance from north-westerly storms, it has been found necessary to prolong the southern jetty, owing to the flood current from the south clashing with the issuing river current, and tending to raise a bar at the mouth. Accordingly, at the present time, the southern jetty, 2,515 yards long, projects beyond the northern one, which has a length of 2,200 yards (Plate 3, Fig. 6).

Though the range of tide at the mouth of the Maas is less than the mouth of the Adour, the works on the Maas have not been designed as if the Maas were a non-tidal river, and dependent for its maintenance solely on the discharge of its inland waters. Indeed, the size and depth of the outlets of the Maas and the Rhine, between Hoek-van-Holland and the eastern Scheldt, are evidently due to tidal influence, as the discharge of these rivers, with their small fall, would be inadequate to maintain the numerous channels by which they enter the sea. The depth, however, at the new outlet has not attained the 23 feet at high water which was considered essential for the growing trade of Rotterdam, and which it was anticipated would be realised by carrying the river channel into that depth of water (Plate 3, Fig. 8).

The deficiency in depth is acknowledged in Holland, and it is plainly indicated on recent charts which show the greatest depth over the bar of the outlet channel to be barely 20 feet at high water; and no vessel drawing more than 19½ feet has gone up to

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Rotterdam. The channel, indeed, is much better, as well as shorter, than the former circuitous channel by the Hellevoetsluis entrance and the Voorne canal, and its influence on the trade of Rotterdam is amply proved by the tonnage of the vessels entering and leaving the port having increased from 2,300,000 tons in 1869, to 3,463,000 tons in 1875.

The deficiency in depth at the new outlet has been attributed by some persons to the amount of widening out given to the regulated channel between Vlaardingen and the sea. Thus the increase in width in proportion to the length of the river between Vlaardingen and the sea was fixed at 20·5 in 1,000, whereas the enlargement in the case of the Seine embankments is only 5 in 1,000. This view would be deserving of more consideration if the Seine works had proved a thoroughly satisfactory instance of tidal river training. It is clear, however, that the tidal capacity of the Seine has been unduly reduced; and effects which may perhaps prove only an inconvenience on the comparatively unencumbered shore in front of the mouth of the Seine, would probably be fatal to the maintenance of a navigable channel on the flat shore of the North Sea opposite Hoek-van-Holland.

The Author thinks that the unsatisfactory condition of the new outlet of the Maas must be attributed to other causes. The tendency of the mouths of the Maas has been to improve towards the south-west, and Mr. Caland has brought back the main outlet to the most northern branch: this was unavoidable for the purpose of obtaining a direct channel to Rotterdam, but it is in opposition to the natural forces in action along that part of the coast. Whilst, moreover, the tidal rise is less than further to the south, some portion of the ebbing waters is lost by a diversion of the flood waters into the old Maas, opposite Vlaardingen, which do not return on the ebb. The branch channel through which this loss takes place could not be closed in consequence of the necessity of keeping open the communication with the Voorne canal.

It was intended that the river should widen out regularly between Vlaardingen and the mouth; but the cut across Hoek-van-Holland is a comparatively deep and narrow channel connecting the wider river above with the channel between the jetties, which were placed the proposed width apart (Plate 3, Figs. 6 and 8). This forms, in the Author's opinion, a notable defect in the work as executed, though not forming part of the original design, and it resulted from the method of carrying out the work. The cut through Hoek-van-Holland was only partially executed by manual labour, and it was widened and

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deepened by the natural scour of the current when the water was admitted into the channel. Considering that four-fifths of the excavation of the cut was accomplished by natural scour, aided by dredging, the economical advantage of the method adopted is sufficiently evident. The result, however, has been that a much narrower, though deeper, channel has been formed in the cut than between the jetties, the width of the cut being only from 820 feet to 1,150 feet, as compared with 2,790 feet at the shore end of the jetty channel. A great irregularity in the channel is thus produced, which is unfavourable to its maintenance both above and below the cut, and must interfere with the free admission of the flood tide. These causes are sufficient to account for the depth at the entrance being less than was anticipated when the design was decided upon.

The great change, however, which has occurred in the foreshore at the new outlet since the commencement of the works may be traced to other circumstances, and it is the principal cause of the depth at the outlet being less, instead of greater, than before the river discharge and tidal current were concentrated upon the sea bottom at the end of the jetties. The progression of the foreshore, the Author thinks, must be due to two causes. One cause is the littoral drift of sand, produced by the flood tide from the south, and by the waves during north-westerly storms from the north. This progression is similar to that which has occurred at all the jetty harbours along the coast south-west of Hoek-van-Holland, and at Ymuiden on the north, and was doubtless anticipated. The other cause is one peculiar to the method in which the work was carried out. The jetties were commenced before the cut was formed, and, acting like groynes on the sandy coast, sand accumulated on each side of them, so that the shore advanced both outside and inside the jetty channel. As stated above, the cut was mainly formed by the scour, which drove the sand from the cut into the channel between the jetties; and the successive changes in depth which occurred during construction in the neighbourhood of the jetties are shown on a coloured chart which has been published by the Dutch Government. A considerable quantity of the sand washed from the cut settled along the inside of the southern jetty; a portion of this deposit still remains there, and the remainder of the material from the cut has doubtless aided the progression of the shore, not merely on each side but also in front of the outlet channel. Thus the 5-metre line, which formerly approached to within 1,100 yards of the coast at the site of the works, is now about 820 yards beyond the ends of the jetties in the centre

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line of the channel, though the south pierhead just overlaps it. The end of the north jetty was built in 26¼ feet of water, but the depth there now is slightly under 16½ feet; and the 5-metre line extends out a long distance in front of it. If all the material from the cut could have been entirely removed instead of being washed into the jetty channel, it is possible that the tidal scour and river discharge might have maintained a deeper channel; but the new outlet has been burdened from the outset with the main portion of the sand from the cut, which it appears incapable of scouring away. Motives of economy very reasonably precluded any other course than the one adopted for such a large undertaking; but the partial disappointment which has attended this well-designed scheme of improvement may be traced to the method of execution. The Author has been led to this conclusion from the indications presented in the charts showing the various stages of the works, and from the consideration that no other sufficient cause exists why the progression of the foreshore should be so much greater at Hoek-van-Holland than at Ymuiden, or even at Ostend. Neither of these latter ports indeed are liable to be encumbered with river alluvium like the outlet of the Maas; but the detritus from inland which reaches the mouth of a tidal river is always small, and could not account in the case of the Maas for the large advance of the shore which has taken place in front of the jetties.

Training Works through Estuaries.

No exact parallel to the Seine regulation works exists in England. The reclamation works on the river Dee perhaps resemble them more nearly than any other works in a tidal estuary in this country, but they were not conducted with due regard to the improvement of the river navigation, which would have indicated the Cheshire shore as the side along which the channel should have been trained. The silting up of the estuary of the Dee was accelerated by the works, just as is happening in the estuary of the Seine, and this appears to be the inevitable consequence of any considerable restriction of a tidal estuary. Moreover, both the Dee and the Seine embankments show, that whenever such works are commenced, they must sooner or later be prolonged to the mouth of the estuary to maintain the navigable channel below, as the embankments in the upper portion of an estuary produce a rapid deterioration in the lower portion.

The Fen rivers falling into the Wash present some resemblance, on a small scale, to the estuary of the Seine. Every extension of

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the embankments of these rivers leads to land reclamation; and in order to maintain them as navigable channels it will be necessary, first to train them to the existing deep water, and then, as the estuary silts up, to prolong the training works towards the open sea.

Proposals have been made at various times for improving the Mersey above Liverpool by restricting its channel between embankments; but the experience derived from the Seine works serves rather as a warning against carrying out any such scheme, lest, in improving the navigable channel up to Runcorn, the channels between Liverpool and the sea should be injured.

The estuary of the Scheldt is deteriorating, though hitherto the depth of the winding channel through it has sufficed for the requirements of navigation. The rapidly-increasing trade of Antwerp, however, renders the maintenance of the depth of the navigable channel a matter of great importance; and the regulation of the river has already been under consideration. Mr. Bouniceau considered that it would be difficult and very costly to embank the Scheldt in the same manner as the Seine, on account of the distance out to sea that the embankments would have to be carried, and owing to the scarcity of suitable materials.[1] Mr. Caland proposed, in 1861, the regulation of the river to a moderate extent by embankments shutting off indents, easing bends, and giving the channel generally a more regular form gradually increasing seawards.[2] Recently Baron Behr has proposed a scheme which he terms the "clydage" of the Scheldt.[3] It consists in training the river between banks so as to form a comparatively narrow channel slightly widening out as it approaches the sea; and it would lead to the reclamation of six-sevenths of the existing estuary. When, however, it is borne in mind that the barring of the East Scheldt was objected to by several engineers as being liable to cause a deterioration of the western branch, and still more when the results of the Seine regulation works are considered, such a proposal appears of doubtful expediency. The Seine, moreover, opens on to a rapidly-shelving shore, whereas the mouth of the Scheldt is encumbered with numerous sandbanks which would render large reclamations in its estuary peculiarly hazardous, unless the training banks could be prolonged into deep water in the open sea.

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[1] "Études et Notions sur les Constructions à la Mer." M. Bouniceau, p. 169.

[2] "Étude sur l'effet des Marées dans la partie maritime des Fleuves." P. Caland, p. 79.

[3] Travaux Hydrauliques, Chambre des Représentants Belgique. No. 174, 1878, p. 36.

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The works on the Tyne bear some analogy to those on the Maas, as regards the training of the river, and the conveyance of the river channel into deep water by means of piers projecting from the shore. Whereas, however, the Maas is led into the sea between slightly diverging piers, resembling the jetty harbours of the North Sea, the Tyne breakwaters are placed wide apart at the shore and converge towards the outlet, like most of the harbours on the English coast (Plate 3, Figs. 9 and 10). The channel of the Tyne also has been chiefly improved by dredging, whereas natural scour has hitherto been mainly relied upon for deepening the outlet of the Maas.

Concluding Remarks.

In conclusion, the Author must acknowledge his obligations to the following publications for information with respect to the early history of the foreign harbours described:—"Notice sur les Ports de la Manche et de la Mer du Nord," by Mr. Dumas-Vence; "Ports Maritimes de la France;" "Annales des Travaux Publics de Belgique;" "Cours de Construction des Ports de Mer," Minard.

He is also much indebted to Mr. Eyriaud-des-Vergnes, Mr. Guillain, and Mr. Vétillart, the engineers of Dunkirk, Boulogne, and Calais harbours, for the latest plans of those harbours and other details; also to Mr. Parkes for information about Madras harbour and a plan; and to Mr. Pettit, the engineer at Bayonne, for a recent chart of the mouth of the Adour.

He has brought forward the general subject of harbours and estuaries on sandy coasts in the belief, that a brief survey and comparison of the past and present condition of some of the most important continental works, so situated, would be of some value to The Institution of Civil Engineers. He has also ventured to express his views of the causes which have produced changes in the state of the harbours and estuaries described, in the hope that the opinions of others may thereby be more readily elicited, and that thus this difficult and important question may receive a full and careful consideration.

The Paper is illustrated by a series of diagrams from which Plates 1, 2 and 3 have been prepared.

[Appendices.

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APPENDICES.

APPENDIX I.

Dredging Operations at Dunkirk Harbour.

Sand pumps are exclusively used for dredging the approach channel to the port beyond the pier-heads. These pumps, which are rotatory, are placed on hopper barges. They draw up a mixture of sand and water which are deposited in the hopper of the barge. The stream of sand and water pumped up flows at the rate of 10 feet per second, which would suffice not only to draw up sand less fine than that at Dunkirk, but also coarse gravel, as sounding leads have been drawn up by it. The solid portions only of the sand and silt lifted by the pumps are deposited in the hopper; the water and the suspended silt are discharged overboard into the sea. The cost of dredging has hitherto been large, as it is estimated that the dredgers can only work about half the year; for waves exceeding about 2¾ feet in height put a stop to the work. The actual cost price of raising and removing a cubic yard of sand is 5½*d.*, exclusive of cost of plant and interest; the contract price is considerably higher.

APPENDIX II.

Port of Dunkirk.

Table indicating the trade of the port in 1860, 1870, and 1880.

	1860.	1870.	1880.
	Number.	Number.	Number.
Vessels entering the port	2,695	2,803	2,986
Vessels leaving the port	2,646	2,810	3,020
Total number of incoming and outgoing vessels	5,341	5,613	6,006
	Tons.	Tons.	Tons.
Registered tonnage of incoming vessels	281,499	492,759	847,797
Registered tonnage of outgoing vessels	284,512	485,446	869,929
Total registered tonnage of incoming and outgoing vessels	566,011	978,205	1,717,726
	Tons.	Tons.	Tons.
Imports	319,945	620,000	1,257,762
Exports	164,304	151,000	238,754
Total tonnage of exports and imports	484,249	771,000	1,496,516

From the above Table it appears that there has been an increase of 5 per cent. in the number of vessels frequenting the port between 1860 and 1870, and an increase of 7 per cent. between 1870 and 1880.

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The total registered tonnage of the vessels frequenting the port has increased 72 per cent. in the ten years ending with 1870, and 75 per cent. in the last ten years; whilst the total tonnage of exports and imports shows an increase of 59 per cent. in the first period, and of 94 per cent. in the last period. The small increase in the number of vessels, as compared with the increase in tonnage of vessels and merchandise, is due to the facilities afforded for the admission of larger vessels by the increased depth obtained in the entrance channel by dredging.

APPENDIX III.

Boulogne Harbour Works.

The works for the new harbour as executed up to October 1881 are as follows:—

1st. Quarries have been opened out at the top of the adjacent cliff, from whence the stone for the works is procured. The stone for the breakwater, and the earthwork for forming embankments at the base of the cliff, are sent down from the quarry along three inclined planes.

The quarries are unfortunately very troublesome to work, as there is only one bed of stone, averaging 5 feet in thickness, underlying 21 feet of sand or clay. In consequence the average cost of a ton of rubble stone deposited in place appears likely to amount to 5*s.* 2*d.*

2nd. An embankment protected by a sea wall has been formed along the bottom of the cliff to provide a site for workshops and a stacking ground for materials.

The sea used previously to beat against the base of the cliff with such violence that 458,000 cubic yards of the material first excavated from the quarries, and thrown down at the base of the cliff before the erection of the sea wall, were soon carried away without leaving any trace on the adjacent beach.

3rd. The rubble base for the south-west breakwater has been carried out to a distance of 2,530 feet from its shore end (Plate 2, Fig. 4).

4th. The superstructure of the south-west breakwater founded on the rubble base at the level of low-water neap tides, and raised 6½ feet above the highest tides, has been built for a length of 1,320 feet (Plate 2, Figs. 3 and 4).

The total cost of the works is estimated at £1,280,000.

It is proposed to erect eventually, within the sheltered area of the harbour, a series of jetties, or quays, 660 feet wide, and separated by tidal basins from 500 to 660 feet in width, extending these works by degrees according to the requirements of the trade.

A portion of the area of the harbour will be deepened by dredging, reserving the deepening of the remainder till it is needed. The dredging will be easily effected to a depth of about 16½ feet below low water, as only sand is met with down to that depth in the part to be dredged. Any further deepening, however, would be costly, as clay mixed with layers of schistous rock lie below the sand.

Mr. Guillain considers that it would be preferable to construct docks rather than the tidal quays proposed, owing to the inconvenience of tidal basins when the rise of the tide amounts to from 23 to 26½ feet.

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Discussion.

Mr. L. F. VERNON-HARCOURT said that without wishing to limit the scope of the discussion, he ventured to suggest one or two points which appeared to him to be the most unsettled in the subject under consideration. With regard to the extension of jetties, the plans of Dunkirk and Calais showed there could be no doubt that that extension had led to no good result. But there remained the question of sluicing basins. Certainly at Ostend that method had been successful; at Calais a large sluicing basin was being carried out close to the east jetty, but at Dunkirk the engineer considered that sluicing basins were of no special value. It seemed curious that there should be such a difference of opinion. It appeared to him hardly possible that a sluicing basin should be useful at Ostend and at Calais, and not at Dunkirk. The extent to which dredging could be advantageously carried for deepening the entrance channel to a port depended on the prosperity of the port. The best forms for harbours on sandy coasts was a question of great interest. With reference to estuaries, one could quite understand that the widening out of the banks might require to be very different where there was a different rise of tide, and a different discharge of fresh water; but it was curious to note the differences existing in the views of engineers with regard to the proper widths between the Seine embankments, and how far down the banks should be carried. There was also a great difference of opinion as to what plans should be adopted for the improvement of the Scheldt. Those appeared to him to be the important questions to be considered, and he asked for the co-operation of others in putting those matters upon a more satisfactory, and perhaps a more scientific basis. Mr. Vernon-Harcourt.

Mr. WALTER R. BROWNE desired to call attention to a memoir on the same subject, which, having been recently published, was perhaps not in the Author's possession at the time his Paper was written. It was by Mr. Keller, Government engineer of Berlin, and it had lately appeared in the "Zeitschrift für Bauwesen."[1] As an abstract had already been given in the Proceedings,[2] he need not further allude to it; but anyone who would refer to the original, Mr. Walter Browne.

[1] Vol. xxxi., p. 175.

[2] Minutes of Proceedings Inst. C.E., vol. lxvii., p. 455.

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Mr. Walter Browne.

could not fail to obtain valuable information, from the way in which the principles and the practice of harbour construction on sandy coasts were set forth. One point was there clearly stated, what he thought the Author had not quite so distinctly brought out, viz., the difference between estuaries and harbours, or as he should prefer to say, estuaries and bays. The Author did not precisely indicate that estuaries and bays (regarding a harbour like that of Madras as an artificial bay) were distinct, not only in shape and appearance, but in the principles which should guide engineers in improving them. With reference to such an estuary as the Seine, that was a case of a tidal flow running many miles inland, then coming to rest on the top of the tide, then flowing back again and leaving behind it all along its course a certain deposit of silt, which somehow or other had to be cleared away. In a bay or harbour such as that of Madras, the case was different. The amount of deposit left within the harbour was probably small, and could be easily dealt with; but the difficulty arose from the sandbanks or drifts of sand which were being continually pushed along the coast in one direction or the other by the action of the prevailing winds in the locality, more or less modified by the currents produced by the tides, and which were always tending to close up the mouth of any estuary or harbour formed in such localities. That was obviously an entirely different phenomenon from the deposit of silt by the run of the tide up a river, and the two had to be dealt with in different ways. In regard to estuaries, he might point out that there were in the Paper two instances of the correctness of some views he had ventured to advocate before the Institution last year. One was the case of Ostend harbour, p. 10, showing the impossibility of keeping permanently open, by any system of sluicing basins or otherwise, an artificial creek or tidal channel, where there was no fresh water to assist in the operation. The other was the great benefit which appeared to have resulted to the navigation of the Seine from the frequently condemned practice of embanking the river throughout nearly the whole of its tidal course. The Author stated that the improvement had no doubt been considerable, but that it was nullified, or at any rate modified, by the fact that some silting-up had been produced lower down, beyond the point where the embankments terminated. That brought him to the other case of harbours, because it appeared from the reports of engineers, and especially of Mr. Vauthier, that the only silting-up of any real moment was at one particular point in the actual low-water channel. He

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could not see what harm arose if silting-up was taking place on some of the flats. The water came in over those flats and ebbed back again, and clearly that water was of no use in preserving a low-water channel; while if there was any water coming from above, whether tidal or fresh water, which passed over those flats, and so got to sea instead of going down the low-water channel, that appeared to him to be a distinct disadvantage. It was surely better to keep that water off the flats, and direct the whole into the low-water channel, which was the part that it was desired to preserve clear. The silting-up noticed in that channel was no doubt due to the drifting sand-bank described above, which was not cut through so deeply as before, because there was less water passing out on each ebb. No doubt when the silting had reached a certain level the existing current would be able to deal with it, and it would not rise further, but still that depth might be inconvenient. In all cases of sand pushing across the mouth of a harbour, the principle to be kept in mind, in his opinion, was to concentrate all efforts upon one point, in order to keep a clear and deep channel at that place. If that were done it was of very little moment what happened to the rest of the estuary. He was therefore disposed to disagree with the Author's conclusion that it was desirable to maintain a trumpet-mouth as much as possible in the Seine; he should rather say that the more both the low water and the run of the tide were confined to one particular line of channel the better the results would be, and that the sooner all the flats were turned into good pasturage, if it could be done without extravagant expense, the better. Mr. Keller, in the Paper to which he had alluded, insisted upon the importance of concentrating all efforts upon cutting a channel through the bar of sand outside the harbour, and the means proposed to be adopted for the purpose were worth mentioning. In a case like that of Madras, for instance, Mr. Keller would build a third pier, starting from the short landing-pier shown inside the harbour and running out to the left-hand corner of the entrance, so making two harbours out of one. The space between the jetty and the left-hand pier he would convert into a sluice basin, letting the water flow into it on the flood, then shutting it up by sluices placed close to the entrance until towards the end of the ebb, and then letting it out to scour the sand from the mouth of the harbour. That he proposed to do at every tide, because he very properly insisted that to do any good in that way it was necessary to be always at work. He pointed out the remarkable fact, from the experiments of

Mr. Walter Browne.

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Mr. Walter Browne.

Lenz, that it took ten times the velocity of water to scour up silt which had once become settled and firm, that was required to prevent the silt from settling. It was therefore important that the silt should not be allowed to stay long in one place; but that as soon as it had settled, if not before, it should be stirred up and scoured away. He had no doubt that the method proposed by Mr. Keller would be effective, but it was obvious that it would be very expensive; and he thought that other modes, some of which were mentioned in the same Paper, for simply stirring up the mud just across the bar, so that the ebb tide or the current from any sluices might continually be acting upon it to carry it away, would be equally effective at a much less cost. He might recall attention to the case of the River Avon, which had always entered the sea through two channels, but was made to debouch through one channel, simply by the action of the tugs belonging to the harbour taking one channel instead of the other close upon low water, and stirring up the mud with their paddle-wheels. He was inclined to think that constant work of that sort, which would be comparatively inexpensive, would answer the same purpose as the more elaborate expedient proposed by Mr. Keller.

Mr. Thorowgood.

Mr. F. N. THOROWGOOD, as superintendent of the Madras Harbour Works, wished to make a few remarks about the movement of sand in the Bay of Bengal. He had had a great deal to do with it, and knew that it offered many difficulties. There were two movements of the sand in the bay. One was caused by the waves, and was almost entirely from south to north. For a small portion of the year, during the north-east monsoon, sand travelled from north to south; the proportion of such sand was not, he thought, more than a seventieth part of that which travelled from south to north. In constructing the Madras Harbour, the great difficulty was to run out the south pier with sufficient rapidity to prevent the sand from passing round the end and coming into the harbour. In fact, a small portion did come into the harbour, and the shore was in a slight degree advanced. But besides that, from February to September there was a totally different movement of sand, which the Author had not referred to, because possibly it was only known to those who were on the staff of the works, namely, a movement from east to west. The deep sea sand, in about 4 fathoms of water, came right in towards the shore, and that caused one of the greatest difficulties in constructing the first 400 feet of the breakwaters, for one morning the rubble base on which the two piers were constructed

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was perfectly free from sand, and the next morning it was covered 8 feet deep with sand, the work then being in 4 fathoms. He thought that such an extraordinary thing ought to be mentioned. The evil was not a permanent one; by means of many experiments and trials to get through the sand which covered the base, the difficulty had been overcome, and it did not again occur. But outside the two breakwaters it was still found that before the corners had been turned, there was always a coming in and a going out of a bank of sand, which seemed to get to its highest in about 4 fathoms. The Author stated that he did not imagine there was a general fear that the harbour would silt up from sand carried by the current entering in at the mouth. Mr. Thorowgood did not think there was any fear of that, because he thought that the movement of the sand under water was confined to the movement in and out again. No sand was brought in and left there; but as long as the waves acted, as in the Bay of Bengal they almost always did, parallel to the coast, from some reason, in about 4 fathoms, they seemed to heap up a mound in one part of the year, and to take it away in another part of the year; and it was only in building through that mound that it was found inconvenient. The accumulation of sand on the right-hand side of the south pier was no doubt a great evil. The Author had referred to it, and stated that although Mr. Parkes said it regularly advanced, the advance was so slow that no danger was to be apprehended. Mr. Thorowgood thought it was rather quicker than was at first anticipated, but he did not think there was any reason to suppose that the harbour could not be made efficient in consequence of the advancing of the sand outside the south pier. The damage referred to by the Author to the breakwaters, and the construction of the breakwaters themselves, might afford a subject for a separate Paper. With regard to the remedial measures proposed by Mr. Browne, he thought the tide was so very small there—about 2 feet 9 inches, and at the equinoctial spring tide only 4 feet 10 inches—and also so sluggish, that there was not sufficient scour to do away with silting, if there was any, at the mouth of the harbour; but judging from repeated surveys, almost up to the last day when he was in Madras, there never had been the slightest indication of any shallowing at the mouth, or anything in the way of silting-up, except from the wave-borne sand, which was arrested mechanically by the solid obstruction of the south pier. He did not, therefore, think the making of a silt basin would justify the expense which it would involve.

Mr. Thorowgood.

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Mr. Browne. Mr. W. R. BROWNE said he had merely alluded to Madras as the only plan exhibited showing the shape of harbour to which the method he referred to was applied. He had no intention of suggesting it for Madras itself.

Sir John Hawkshaw. Sir JOHN HAWKSHAW observed that although the Paper dealt with a number of harbours, and therefore necessarily dealt with them cursorily, he thought the observations made with regard to them were generally judicious. But, in considering a Paper of that kind, dealing with so many cases, it was impossible to enter upon a general discussion of them all. With reference to harbours there was nothing more certain than that each one must be dealt with according to its own special *régime*. It was impossible to lay down general principles to apply to all the various cases, which were exceedingly complex. They must all be considered with regard to their peculiarities, and the means of treating them must have reference to those peculiarities. With regard to several of the cases mentioned, he had had personal knowledge, and had made reports upon some, and given designs for others; and some of them he had carried out. In the case of Boulogne, he had recommended a plan for dealing with that harbour, and he approved of what was being done there, because it closely resembled what he had himself suggested. The contrary was the case with regard to Calais. He had suggested a mode of dealing with that harbour which, in his judgment, would have been more efficient than that which had been adopted, namely, the method of sluices, which the French were often inclined to adopt. They were proposing to make up for the loss of water which formerly flowed behind Calais, and which, as the Author had pointed out, had been restricted, and encroached upon, leading to the damage of the harbour, by making a basin upon the shore of about 200 acres, to receive the tidal water, and by sluicing to force the bar further from the entrance to the piers. That was not his method, and he did not think it as good as the one he had suggested. Though it was difficult to lay down general principles, there was one which he thought did apply to the piers at Calais and to the piers at the Maas, and to other cases of that kind. The solid portion of the piers at Calais, for instance, and at the Maas, had been made half-tide high. He knew that at Calais this had been done designedly, for he had discussed the matter with French engineers, and he believed that they were wrong. Their object was to let the sand, which travelled along the coast, enter the channel; and they assumed the power of sluicing would be sufficient to take it out to sea. Of course, the distance it would

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take it would depend upon the sluicing power; but it took it, in fact, to the bar, and there deposited it. He thought the piers would be better if they were made solid up to above high-water mark. It was true (and that was their reason for not doing it) that the sand would by piers so raised be turned outwards towards the end of the piers. But he believed it would only travel until it came to a certain depth of water; and, at all events, if it did travel further it would only require the lengthening of the piers, and he thought that method was better than letting the sand pass into the channel for the purpose of having to sluice it out again. With regard to the Maas, he agreed with what the Author had said as to the works there. He had been acquainted with them from their early progress to their completion. He thought the Author had reasoned rightly with respect to them. It would be seen in the first place that the channel inland was narrow, that the width between the piers out to the sea was very great, more than double the width of the channel, and that was enough to account for a portion of that which had happened. The channel was a new cut, and the water of the Maas had been turned into it when only a narrow gullet had been made and forced the sand into the sea. The sea there was shallow, and the sand fine, and consequently the floating of that immense mass of sand into so shallow a sea necessarily led to mischief. There was another reason which the Author had not alluded to, but which, he believed, had also had the effect of disappointing those who carried the plan out. The solid part of the piers was carried only to half-tide level. On the southern side of the piers there were immense masses of shifting sand, which travelled in rough weather, and at that part of the coast the sand mixed with water passed over the piers, and the moment it got inside, of course it dropped and was there deposited; the result was that though the engineers were aiming at a depth of 22 feet of water, they had only a depth of about 11 feet. He might mention that the same thing had happened at Port Said. The pier was run out a long distance into the sea, but the blocks were at first too few, and the waters passing towards the Bay of Pelusium, carrying with them the waters of the Nile, flowed through the spaces between the blocks, which were large, and, of course, the moment the water got inside it deposited its alluvium. That was not designed to be so, but the blocks were run out in that way at first on the question of expenditure, and on the ground of time. It was intended to deposit more blocks until the passage of the water through the piers was

Sir John Hawkshaw.

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Sir John Hawkshaw.

obstructed, and it was compelled to pass round the end of the piers. As to whether there would be a deposit or not in a case like the Madras harbour, it would depend upon whether the water in rough and stormy weather mixed with or raised matter light enough to be deposited when the water was still. If it did so in a harbour of that shape there must necessarily be some deposit. He did not mention that with a view of bringing any accusation against the design, because it applied to his harbour at Ymuiden, which had something of the same form, and where there was fine sand, and some deposit in the interior of the harbour. There were cases, where a harbour could not be made which would not silt up to a certain extent, and the evil could only be remedied by dredging away the material from time to time.

Mr. Redman.

Mr. J. B. REDMAN said that the Paper might be regarded as an interesting historical *précis*, but it might raise the question in some minds as to the practical lesson to be gained from it. He thought that an examination of the sea-board of the English south-eastern coast told very much the same tale—that if an open jetty was built across a low sandy shore the sand would pass through it in either direction; that if the jetty was close planked the sand would collect on the flood side and on the ebb side; that if the jetty was duplicated in the case of the outflow of a river or the entrance to a natural estuary, there would be a low-water foreshore collection of sand on the seaward side of both the jetties. The charts of the north coast of France, of Belgium, and of Holland, bore testimony to this conclusion. As the jetties were extended in length the foreshore would creep out almost *pari passu*, until at last the tidal effect upon the channel, aided, perhaps, by natural or artificial scour, would be lost, and ultimately dredging must be had recourse to. Undoubtedly the history of those Low Country harbours was to marine engineers very interesting, but to a certain extent it was somewhat antiquarian, because many of the harbours on the Netherland coasts, and on the British coasts, were becoming, like the sailing ships of old that frequented them, things of the past. That was forcibly illustrated by the reports in the Blue Books issued by the Board of Trade. The figures, puzzling at first sight, were again interesting as showing the progress of the commercial marine. The returns proved that during the last forty years the foreign tonnage—goods carried out and home—had increased five or six fold, whilst the proportion of it carried in steam ships had increased fifty or sixty fold. The steam tonnage was now in effect double the amount of sailing tonnage. That,

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however, did not represent the increase, because the construction of very large steamers had advanced at a much higher rate during the last few years. There was an interesting compilation, by Mr. Nursey in a recent number of *Iron*, in which it was shown that since the launching of the "Great Eastern," with the exception of two years in which there were eight or ten vessels of 4,000 tons, until last year, the annual number was much less; but last year there were thirty-three iron or steel vessels of 4,000 tons either on the stocks or launched. Those vessels were entirely independent of circumstances affecting these harbours, and, happily, the great centres of commerce were almost all on large estuaries that required no adventitious aid from piers, as in the case of London, Liverpool, Newcastle, Cardiff, and Hull. With the exception of the Tyne they were all independent of piers. Attention, however, would have to be drawn to the condition of the low-water channels—the estuaries of the Thames with shoals of 20 feet to 22 feet at low water, and the Mersey with 10 feet, could not be made available (as now circumstanced) in the way suggested by the projectors of certain schemes for the Thames—that docks might be made in the lower reaches available at any time of tide. This could not be done without deepening the approaches of the river, so as to make them equal in depth to the reaches from which the docks entered. He could not help thinking that, isolated areas of enclosure by artificial works in deep water, off sandy shores like those of Belgium, might be constructed, so as to be entirely independent of littoral detritus, the works being connected with the shore by bridging or viaducts. Mr. Redman.

Mr. D. HUTTON remarked that the dredging at Dunkirk had especially interested him. At Ymuiden Harbour, where a quantity of more than 8,000,000 tons, chiefly sand, had to be dredged, and it being necessary to begin the dredging before the piers afforded sufficient shelter for bucket dredgers, he was led to design sand-pumps, which were used with success. These had been described by Mr. Hayter in his Paper on "The Amsterdam Ship Canal."[1] One of them was sent as an experiment to the Hoek of Holland, and being found to answer there, others were constructed for that place, modified, however, by uniting the barge and sand-pump in one vessel, and by placing the pump in the centre, instead of hanging it over the stern. From the Hoek of Holland the system was introduced at Dunkirk, and the cost of dredging at that place, namely 5½*d.* per cubic yard, was the same as it was at Ymui- Mr. Hutton.

[1] Minutes of Proceedings Inst. C.E., vol. lxii., p. 23.

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Mr. Hutton. den. This was the cost, exclusive of plant and interest, or, in other words, the actual working expenses. His own conviction was that although the waves in storms had great power in lifting sand from the bottom in water of considerable depth, and could transport it to great distances, yet that generally speaking the tidal current did not carry the sand in suspension, but rather swept or rolled it along the bottom. The difference between the two modes of acting upon the sand was, that if the sand were carried in suspension it would be at the mercy of the current, and would follow its course with little disposition to deviate from it; but if it was rolled along the bottom, the grains of sand, being irregular in shape and weight, would work to one side and form the usual banks on each side of a channel. Further, as the bank formed and the slopes became too steep for the particles to climb, they were swept forward and pushed aside at the end or tail of the bank, or, in the Author's words, "the sandbanks tend to lengthen out towards the east." With regard to the movement of sand on the bottom, he had often, when down in a diving bell, observed the bottom in motion with the tide, but had never seen the sand in actual suspension in the water in moderate weather. Sir John Coode had once mentioned some observations he had made on the Shambles, a bank off Weymouth Bay.[1] The bank consisted of shells much lighter than sand, but, nevertheless, there appeared to be no tendency to actual suspension, although the bottom was in rapid motion. Mud and silt were acted upon in a different manner. Being of small specific gravity, they were carried by the current in suspension and spread over large areas. Hence a mud bar, if the stream of the river could be concentrated on it, would often be swept entirely away, and the mouth of the river effectually deepened for a long period of time. The Author had stated that at Ymuiden the foreshore was advancing. It was plain that the foreshore would only advance until it reached a littoral current capable of keeping it in subjection, a point which was the sooner reached where, as at Ymuiden, the piers converged. Practically, the foreshore at that place had ceased to advance for many years.

Sir John Coode. Sir JOHN COODE agreed with Sir John Hawkshaw that the Paper was a valuable contribution to the memoirs of the Institution, bringing together as it did, in a condensed form, all the salient facts with regard to a series of harbours of, perhaps, the most difficult type that engineers could possibly have to deal with; so that, as a work of reference, the Paper would be exceedingly valuable. He could

[1] Minutes of Proceedings Inst. C.E., vol. xxiii., p. 253.

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wish, however, that the Author had drawn a broader distinction between the action of tidal currents and that of wave currents. It was surprising to find how almost universal was the confusion, at any rate, the want of distinction, between the action of the tidal or littoral currents and the currents generated by wave action. He had referred to this subject before the Institution more than once. The first occasion was in connection with his Paper on the Chesil Bank, read thirty years ago;[1] and since then he had at various times directed the attention of the members of the Institution to this distinction. He now repeated that a gale of wind of twenty-four hours would bring about far greater change in the condition of sandbanks and foreshores than ordinary weather of twenty-four months. It should therefore be always borne in mind that, as a rule, it was to the currents generated by wave action, and not to currents generated by the tide, that those great changes were due. The Author had referred to the jetties or piers at Sunderland at the mouth of the Wear. It was true they had not been extended. The fact was the Sunderland harbour authorities had had their attention directed to the construction and extension of docks since the time of Mr. John Murray, M. Inst. C.E., and they had found it necessary to provide floating accommodation on an extensive scale for the shipping of coal in the docks according to the most improved modern system; consequently they had not been able to expend as much money upon the improvement of the River Wear as they might otherwise have done. He had, however, the honour of advising them a short time ago upon the subject, and they were now about to do two things—to construct extensive outer works in front of the entrance of the river, and to expend a considerable sum of money in improving the upper region of the tidal compartment of the Wear. In that way the scour would be improved, and the trade along the banks of the river, whether in the shipment of coals or in the construction of ironworks, or the further erection of building yards, would be largely developed. But he thought the advantages that would have been derived from the works of the Rennies had not been fully felt, because a few years ago it was discovered that at a very short distance inside the piers there was a mass of boulders *in situ*, which of course had prevented the deepening of the channel. Those had been removed, and some little improvement had since taken place, and he had no doubt that when the upper tidal region of the Wear was

Sir John Coode.

[1] Minutes of Proceedings Inst. C.E., vol. xii., p. 520.

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Sir John Coode. trained and dredged in the way that it was about to be done, a still further improvement would result from the tidal scour alone. Sir John Hawkshaw had anticipated a good deal of what he had intended to say. With regard to Madras, he could not approve of the recommendation made by Mr. Keller. The form suggested would, he thought, be a perfect sand-trap on the northern pier of Madras harbour, and the little rise of tide showed that the scour to be derived from the tide would be of comparatively no value. Mr. Redman had spoken of the effect upon a jetty of a flood tide, and of an ebb tide. If Sir John Coode's doctrine were true, he ought rather to have spoken of the weather side and the lee side.

Mr. Redman. Mr. REDMAN had assumed that the littoral sand was moved both by the flood and by the ebb tide, and that with two parallel piers the sand would silt on the flood and on the ebb sides of the entrance they enclosed.

Sir John Coode. Sir JOHN COODE said his contention was just the reverse—that the effect of wave action was at least a hundred fold greater than that of the tidal action. Mr. Hutton had spoken of the movement of tide in deep water, and had rightly described the facts with regard to the Shambles. He confessed he was much surprised when he went down in a diving-dress himself. It was true that the material of the Shambles was fine broken shell, far more easily moved than sand; it was also true that the sand was in rapid motion, but it was only in rapid motion owing to the obstruction created by his own body. If a stick were placed in a river with a tidal current, it would be seen that there was a considerable amount of agitation and disturbance. He had noticed the same thing in the West Bay when he was down in deep water. The very obstruction of one's body and feet to the run of the tide, created an amount of disturbance in the water and caused the sand to move, but it soon settled down again. Mr. Browne had rightly drawn a distinction between harbours within estuaries and harbours on coasts or in bays. There was a broad distinction between the two, and it certainly should never be lost sight of. As to the bridging, to which Mr. Redman had alluded, he was happy to say that he could agree with him on that point. On certain shores where there was a great amount of sand in motion the true principle of getting over the difficulty was by carrying a viaduct or a bridge into deep water, to a point beyond the disturbing action of the sea. He had lately designed a harbour for an important port in South Africa, Port Elizabeth. It had been proved to demonstration that in that bay the sand had not been disturbed beyond

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a certain depth. A series of sections taken on the same lines from time to time had shown that the movement of the sand from the beach seaward always terminated in about 3½ fathoms. The exact form of the outer sheltering work, to be made of concrete masonry, was open to a little consideration, but the principle was that of going across shallow water, and getting out into a depth of 6 fathoms by means of a viaduct, and there commencing the solid work 3,000 feet in length, which was to afford shelter to the ships that were discharging cargoes. It was a remarkable circumstance that an angle of about 20° would represent the horizontal range of the swell in that bay. He had gone upon the broad principle alluded to by Mr. Redman, of passing beyond the line of disturbance, and he felt assured that there would be no difficulty in the way of silting up. A considerable expenditure would be involved—about a million of money. As often happened in such cases, there was a difference of opinion on one or two points, but a conference had been held on the subject; Sir John Hawkshaw and Mr. Brunlees were appointed to look into the matter conjointly with himself, and they had entirely endorsed his recommendations. He was fully convinced that that was a really safe method of dealing with a sandy foreshore. Sir John Coode.

Dr. W. Pole said it might be worth while to put on record, in connection with the port of Calais, a plan that had been proposed some years ago by Mr. Dupuy de Lome, the Naval Architect to the French Government, and Mr. Scott Russell, for facilitating the Channel passage from England. Starting with the necessity of enabling large ships to approach the land at all times of the tide, and despairing of attaining this by any improvement of the present Calais harbour, they adopted the bold scheme of constructing a sheltered landing-place in deep water, and connecting it by a bridge with the shore. It was found that a sufficient depth could be obtained at a distance of about 1,150 yards from the low-water coast line. The structure was to be in the shape of an annular island, or circular wall, about 1,000 feet in diameter, and as it was designed only for the use of the ferry steamers, the opening was placed facing the land. It was intended that the steamers to be used should be of large size, and should carry the trains over the Strait. The sheltered internal space was to be provided with quays, so arranged as to allow of the trains being landed at any time of the tide, and conveyed at once across the bridge (prolonged by an embankment over the flat shore) to a junction with the Northern of France Railway. It was believed that a harbour so situated would be quite free from any liability to Dr. Pole.

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Dr. Pole. deposit from the littoral drift of the sand. It was estimated that the work could be executed in two years, and would cost, including the ships, about a million sterling.[1] The scheme was viewed favourably by the French Government, but it was stopped by the Franco-German War, and had not since been revived.

Mr. Rendel. Mr. A. M. RENDEL said that about twenty years ago he had designed a similar harbour at Rosslare, in Ballygeary Bay, outside Wexford, which had been partially carried out. He had come to the conclusion that any close harbour there would silt up, and he accordingly schemed the one to which he had referred. It was now about half finished, but, like many other Irish things, it had rather come to a stand-still; he believed there was not sufficient money to carry out completely the solid part of the breakwater. The bridge had been completed fifteen years ago.

Mr. Giles. Mr. A. GILES remarked that the Author had established two prominent facts. First, that it was dangerous to curtail the estuary, and consequently the scouring power of the estuary, through a tidal channel on a sandy coast; secondly, that by the extension of long parallel piers the difficulty of maintaining a good channel was not surmounted. Looking at the long line of harbours from Calais to Gravelines, Nieuport and Ostend, it appeared to him that the directions of their entrances from the sea were nearly parallel; and it was on record that the flood-tide, being much stronger than the ebb, brought the sand with it into those cuts. As the lengthening of those piers, and the extension of the cuts had not had the effect of making good harbours, he wished to suggest that there might be something wrong in the direction of the piers. He agreed with Sir John Hawkshaw that in such harbours as those described on the French and Belgian coasts nothing was known at present that would altogether prevent the accumulation of sand, and that the last resource was dredging; but he submitted that the amount of dredging was a serious question. If by further investigation of the subject it could be proved that the channels, to which he referred, were in a wrong direction, and that they might be improved by being turned a little towards the ebb tide, and on the curve instead of on the straight, it would follow that the channel could be maintained not only as well but a great deal better with less dredging. In regard to the Tynemouth harbour he did not think the same observations applied. The widening out of the piers from the

[1] Transactions of the Institution of Naval Architects, vol. xiii., p. 213.

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shore, and the narrowing of the entrance, had a different object from that which was intended in the other cases; in fact the widening out acted upon that stormy coast as a wave-trap, so that when vessels got within the narrow entrance they were tolerably safe; the sea expanded within the wide part, and naturally became less heavy. He would suggest that on a coast of that description it would be still better if the piers were wider at their base and converged a little more towards the end; they would then form a still better wave-trap. There was a theory that shingle and sand did not travel below a certain depth; and the remark of Sir John Coode with regard to the travel of sand at Port Elizabeth somewhat confirmed that view; but on a sandy coast like that under review it was a very long way from the shore to 21 feet at low water, and the expense would therefore be generally prohibitory. Mr. Giles.

Sir JOHN COODE remarked that the piers at Tynemouth were by no means completed. The intention was to narrow the opening considerably more than at present, so much so that the Tyne Commissioners were now having constructed a heavy crane to extend the piers. That would have the effect which Mr. Giles had mentioned; it would make the piers more converging, and the waves would be dispersed better when the piers were completed. He believed it was intended to carry out the piers another 600 feet. Sir John Coode.

Mr. J. W. GROVER said many years ago he had an opportunity of visiting the works at the mouth of the Maas, and he was much struck by the way in which the piers were made. A number of fascines were bound together on the shore; they were constructed into mattresses of very large area in the first instance; lighters were brought alongside of them, and they were towed into position where the pier was to be; stone was then thrown upon them, until gradually the mattress sank. At the base of the pier they were very large, but the width was reduced as they came up to the level of half tide. When the work was completed a number of piles were driven through, and the pier was formed. It was so simple a way of constructing a pier and breakwater that he was surprised it had not been adopted in this country. He should be glad if the Author would mention the cost of the piers. Some figures that had been given to him by one of the officials had astonished him greatly, and he did not think that works had been executed anywhere else so cheaply. The only point that occurred to him at the time, which was no doubt considered a good deal at Rotterdam also, was the direction in Mr. Grover.

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Mr. Grover. which the piers were run. He believed the opinion was expressed by many eminent Dutchmen, and certainly by the English engineers who visited the works, that the piers would have been much better if they had been brought closer together at the entrance as at Tynemouth.

Mr. Rawlinson. Mr. R. RAWLINSON, C.B., desired to say a few words with regard to the entrance at Ostend. Whatever purpose the open timber piers might serve in affording a low-water entrance into the harbour during a gale, they certainly did not secure a safe entrance at high water when there was any sea on. He had been at Ostend when vessels had had to lay off during one or two tides before they dared try to enter; and he had also been on the pier when a steamer came against the western side, and if she had been five minutes later she would have been on shore. The main purpose of a harbour ought to be to afford safe means for entrance in rough weather, and secure shelter during storms; but for both these purposes the Ostend harbour failed.

Mr. Baker. Mr. B. BAKER said the harbour at Ballygeary had been inspected by General Hutchinson six weeks ago, when Mr. Baker accompanied him as engineer. It had not been carried out to the full extent at present. The solid pier, connected with the shore by an open viaduct, had been perfectly successful as far as the accumulation of sand was concerned, but he was sorry to say there was not very quiet water inside; and captains of vessels generally gave the pier a rather wide berth.

Mr. Rendel. Mr. RENDEL said the pier was designed to be about 1,500 feet long, but he did not think that more than 300 feet had been built.

Mr. Lewis. Mr. W. B. LEWIS said that his late partner, Mr. Purdon, and himself were the engineers who started the harbour. They adopted the suggestion of Mr. Rendel and Capt. Calver in the design. He hardly thought it was a case in point, because nobody would describe that shore as a sandy shore. It was out at sea, and the sea was very rough. No doubt there were currents running right and left, but the shore was not what could be called a sandy one. Mr. Vernon-Harcourt was the resident engineer, and being perfectly acquainted with all the details would no doubt refer to them in his reply.

Mr. Vernon-Harcourt. Mr. VERNON-HARCOURT, in reply, said he agreed with the remark of Mr. Browne, that harbours without any fresh water coming into them should be regarded as totally different from estuaries. He had not classed the two together. No one could say that the Seine or the Maas should be treated like Madras or Ymuiden. It certainly was not the opinion of most French engineers that

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the Seine was in a satisfactory condition. It should be borne in mind that if a channel was contracted, as it had been in the case of the Seine, it must be carried farther out, and ultimately it would come to carrying parallel jetties into the sea; they would then get to the same position at last as that of the ordinary jetty harbours of the North Sea, except of course that there would be a scouring reservoir of fresh water. It might eventually come to that in the case of the Seine, but he thought that that termination should be avoided as long as possible, and that therefore the tidal capacity of estuaries should be diminished as little as possible. Mr. Browne's observations with regard to Madras had been answered by Mr. Thorowgood. He appeared to think that the travel of sand was from north to south, but it was just the reverse. Till the sand got to the front of the present piers he did not see any advantage in extending the work farther than it was: it went into 7½ fathoms, and that surely was a sufficient depth for the piers to be carried. Mr. Browne had mentioned with approval a proposal by Mr. Keller to improve the depth at the entrances of what might be termed closed harbours, such as Madras, by converting half the enclosed space into a scouring basin. A harbour like Madras or Boulogne, would require to be greatly enlarged if half its area was thus rendered useless for vessels. He was of opinion that it would be far better to devote the additional expenditure towards carrying the breakwaters into deeper water in a case like Boulogne, obtaining at the same time a still larger sheltering area, rather than resort to the expedient proposed, which would be of little value if the entrance was in deep water, even with a range of tide like that at Boulogne. Dredging would be a cheaper and better method of removing the bar than Mr. Keller's scheme. With regard to Madras harbour he might mention that Sir Andrew Clarke did not at all approve of the design, and that he proposed to have a breakwater some distance out; and to connect it with the shore by a viaduct on concrete pillars, so as to leave the littoral drift from the south to the north unimpeded as far as possible. Sir Andrew Clarke's design, as explained to him, was very similar to the plan adopted by Sir John Coode for Port Elizabeth, and had the same object in view; namely, to bridge over the zone of disturbance near the shore by an open viaduct, and then place sheltering breakwaters in a depth where no deposit was likely to occur. Sir John Hawkshaw had referred to the fact of the Maas jetties having only been carried up to the half-tide level. There was, no doubt, the objection that the sand might be brought in and settle in the still water

Mr. Vernon-Harcourt.

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Mr. Vernon-Harcourt.

between the jetties. But it was certainly a plan that had been adopted at all the jetty harbours, and perhaps the projectors did not feel justified in departing from the general rule. The success, however, attending Ymuiden, Madras, and other harbours, would seem to justify the jetties being carried up above half-tide level. It was intended in carrying them up merely to half-tide level to facilitate the introduction of the flood tide, but, of course, with such a narrow cut at the entrance of the river, the free admission of the flood tide would be of comparatively little value. With reference to the advance of the foreshore at Ymuiden, he had only mentioned that there had been such an advance. He was glad to hear from Mr. Hutton that it had reached a position of equilibrium, such as he had expressed a hope in his Paper might be reached, and which Sir F. de Lesseps had said had been reached at Port Said. With reference to the Tyne, the diagram showed the piers as completed; but the plan which Mr. Giles proposed for spreading the breakwaters farther out at the shore end had been carried out at Sunderland in the piers for the dock works. They started far apart at a sharp angle from the shore, and converged to a moderately narrow entrance at the ends. Mr. Grover had asked what was the cost of the Maas piers? He believed that their cost averaged about £118 15*s.* per lineal yard, with an average height of 16 feet. It had been suggested by Mr. Lewis that he should give some details about Rosslare Harbour in Ballygeary Bay, having been in charge of the works for two years at their commencement. The bay lay on the south-east coast of Ireland, between the entrance to Wexford Harbour and Greenore Point. The harbour was situated about 1¼ mile to the north-west of Greenore Point; it was constructed in order to afford access for steamers of greater draught than Wexford Harbour could admit; and a railway was made at the same time from Wexford to the harbour. The site, being only about 65 miles from Milford Haven, was considered peculiarly favourable for the development of a packet service with England. Though, as Mr. Lewis had said, the coast line did not resemble the flat sandy shores of the North Sea, for it consisted of clay cliffs with boulders and rock interspersed along the shore, yet the adjacent foreshore was subject to the travel of sand, and large sandbanks existed farther out in the bay. The plan of the harbour was shown on Fig. 1 (next page); and the original design resembled, on a small scale, Sir John Coode's sketch of the harbour at Port Elizabeth. The approach to the pier was formed by an embankment across the beach to low-water mark; and directly this work had been executed, sand began to accumulate on its south-eastern side.

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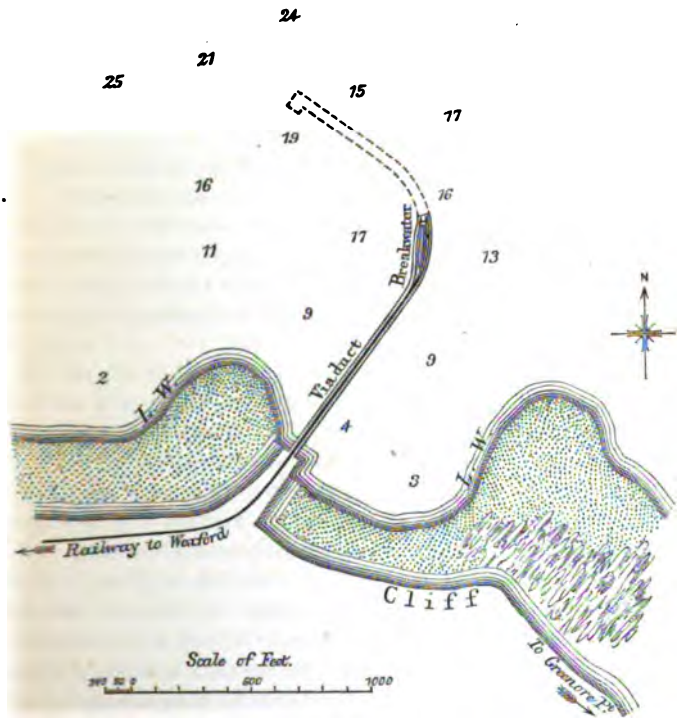
Mr. Vernon-Harcourt.

The railway was then carried straight out from the shore on an open viaduct formed of iron girders resting upon concrete piers. Twelve out of the twenty-four piers were built under his supervision with concrete deposited *in situ* within frames, each pier forming a single mass of concrete. A solid breakwater, composed of two concrete block walls with rubble filling between, was carried out from the end of the viaduct. It had been intended originally

FIG. 1.



ROSSLARE HARBOUR IN BALLYGEARY BAY.

NOTE.—The soundings are in feet. The dotted lines show the breakwater as originally designed.

to curve the breakwater round till its direction was at right angles to the viaduct, and then to continue it in a straight line, in a depth of about 19 feet at low water, as shown in the figure. The straight portion was designed to serve both as a quay and for the protection of vessels from north-easterly winds; and the curved portion would protect vessels alongside the quay from south-easterly winds; whilst the coast line of the bay sheltered the harbour from the west.

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Mr. Vernon-Harcourt.

Want of funds, however, had prevented the completion of the scheme; only a portion of the curved part of the breakwater having been built, giving it a length of 300 feet instead of 1,000 feet. The harbour, therefore, as executed (Fig. 1) was open to the north-east; and it was natural under these circumstances that, as stated by Mr. Baker, the shelter was bad. A packet pier only had been proposed from the outset, and not a regular commercial harbour; and even had the breakwater been completed, the harbour would have been deficient in shelter from the east and south-east except for vessels alongside the quay. He believed, however, that the design was the best that could have been adopted for the special object in view, and in that particular site; and he was convinced that if the viaduct had been made solid a considerable advance of the foreshore would have occurred. The great difficulty in all such cases was to secure an adequate protection without interfering with the travel of sand. He had seen a design for a harbour at Madras in which a sheltered area was enclosed between two curved breakwaters in deep water, the inshore breakwater being connected with the land by an open viaduct; thus realising the suggestion made by Mr. Redman, and resembling the scheme referred to by Dr. Pole.

Mr. Giles had drawn attention to the fact that all the North Sea jetty-harbour channels pointed towards the north-west, and suggested that by curving them round towards the north-east at their extremities, away from the sand-bearing current, they might be more easily maintained. The engineer at Dunkirk had informed him that the alteration of the line of the entrance-channel to Dunkirk harbour was under consideration, because the existing channel was so long and too narrow. It was proposed to form a new channel straight out to sea, not apparently with any notion of thereby preventing the introduction of sand, but with the natural expectation that a shorter channel would be cheaper to maintain. He thought that the coincidence of the line of the jetty channels was too marked to be due in every case to accidental circumstances. It seemed probable that the slanting course was adopted in order that the sluicing current might not clash with the ebbing tide, and as being more favourable for the entrance and exit of vessels trading with westerly ports. The curving round of the channel, proposed by Mr. Giles, would be advantageous in hindering the admission of sand; for whether the sand was carried along by the tide or by the waves on that coast, it would mainly come from the west, as westerly storms were the strongest in that locality, and therefore both the tidal action

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and the wave action tended to heap up the sand upon the western side of the jetties more than on the eastern side. Such a direction, however, would not be favourable to the maintenance of a harbour by sluicing, which was always effected during the ebb. Mr. Vernon-Harcourt.

The difficulty, in a situation such as Dunkirk or Ostend, of introducing the system of an outer breakwater connected with the shore by an open viaduct, consisted in the small depth of water attainable near the shore and the exposure of the straight line of coast. The establishment of a breakwater on an outlying sandbank might lead to an extension of the sandbank, as had happened at Calais; and the more the shelter provided between the breakwater and the shore the more it would favour the deposit of sand brought along by waves. He considered that the best prospect of maintenance on such a flat sandy coast would be to form the harbour with solid piers, starting from the shore at some distance apart and converging at their extremities, which should be carried into as deep water as practicable. If circumstances admitted of a choice of site, it should be selected where a good depth of water approached nearest to the shore, and where the piers would project most beyond the adjacent coast so as to secure a scour across the entrance.

Correspondence.

Mr. Russel Aitken believed it would be found cheaper to treat some harbours by means of short jetties, and a considerable amount of continuous dredging, or by continuous dredging simply, without jetties. At the harbour of Calais the chief engineer had shown him the plans of the dredging which had been carried out since June 1881. The bar had been reduced by 5 feet in height, and there could be no doubt that the depth of 10 feet at low water, which was aimed at, would be attained at very little cost. Some sand was brought along the coast from the westward, and found its way round the end of the west pier. The cost of dredging had lately been much reduced, and in the case of Calais it was contracted for at the rate of 7*d.* per cubic yard. Many works therefore could be more cheaply done by dredging solely than by dredging in combination with piers; although in some cases, such as at the mouth of the Tyne and at Ymuiden, long piers were necessary to shut out the waves and to quiet the water in the harbours. Mr. Russel Aitken.

Kurrachee harbour was an instance where the Manora breakwater might have been dispensed with at the cost of some extra dredging. Of course the breakwater was useful to a certain extent in quieting the water in the harbour; but the sand moving from

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Mr. Russel Aitken.

the westward had been carried, or would shortly be carried, round the end of the breakwater on to the site of the former bar, where it would be deposited and have to be dredged away. The interest on the money which had to be expended on even a short length of breakwater would pay for a considerable amount of dredging.

Mr. Caland.

Mr. P. CALAND furnished some details of the works for the new entrance to the Maas. The scheme for improving the New Maas, and making a cut through the Hoek of Holland, proposed to give the river a funnel shape, following regularly lines with increasing breadth downwards, corresponding with the greater difference between high and low water towards the sea, and consequently with the larger quantities of water that had to be discharged. In order to provide a suitable depth at the mouth, two piers were projected and added to the plan, between which the new river was to debouch, while to increase the discharge, and to prevent the influx of sand from the sea, it was proposed to cut away the easternmost point of the island of Rozenburg. In this way the Old Maas would be led into the Scheur, and be of service in scouring the part of the new river along Rozenburg. In connection with this a gradual enlargement of the new river-bed near Vlaardingen was proposed. The works at the Hoek of Holland were started first. The piers in the sea were built, and the cut through the Hoek made, the latter on a much larger scale than was originally proposed; and as the cutting went on, the old branch, the Scheur, was checked with the object of entirely stopping it as soon as the cutting was sufficiently advanced. In 1871 it was thought the proper time had come for this. The Scheur was completely stopped, and the cut grew wider and deeper from the effect of the stream, so that on the 9th March, 1872, the first ship went out to sea through the new channel. This was the steamer "Richard Young," running between Rotterdam and Harwich. The smallest depth in the new fairway was then about 6½ feet at ordinary low water, and this depth continually increased till in the winter of 1875–76, when it amounted to 13 feet at ordinary low water, and to 19½ feet at ordinary high water. But in the winter mentioned there was a continuance of extraordinarily high freshes (*opperwater*) along with heavy gales, which lasted about two months. This caused not only a great discharge of sand and mud from the rivers, but the action of the tides in the new river mouth was greatly interrupted. There were days on which there were actually no flood tides in the river mouth at the Hoek of Holland. These causes induced silting to a somewhat less depth than 11½ feet at low water; and as it was evident that the

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cut through the Hoek (only averaging 650 feet wide) was much too restricted in proportion to the width upstream and between the piers, it was determined to enlarge it. This was done, and the cut at present was about 1,640 feet across. As a result of this work the current had become much more powerful, and the water escaped to the sea in a straight line. By this a new channel was now opened southward of the former one in the direction of the cut, and which would certainly be the channel of the future. It was also beyond doubt that this channel would be much deeper if the cut through the Hoek of Holland were made according to the original scheme, that was from 820 to 930 yards wide. The cut was at present being enlarged, but pecuniary difficulties prevented its proceeding with desirable speed. Had the plan been carried out in full no doubt the proposed depth of 23 feet at high water would have been acquired, which was only 3½ feet more than had been obtained once, and would be obtained again. Recent soundings indicated a depth of 13 feet at ordinary low water in the south channel. Mr. Caland.

As regarded the Author's statements, it might be observed that the present mouth of the river was in the same place as the former, which was used when William III. was King of England, and that instead of the bar enlarging towards the sea, on the contrary it was decreasing, so that the contour lines of soundings were extending landwards instead of seawards. The bar was thus scoured away by the flood and ebb tides of the sea, and the surface of the upper levels was also lowered by the same currents. The whole scheme depended on the execution of the plan as projected, and in that case the Old Maas would supply water to the Scheur instead of deriving it thence, as Mr. Vernon-Harcourt supposed. Mr. Caland was more in accord with what the Author put forward on page 279 of his recently published work on rivers and canals than with the contents of the present Paper.

Mr. W. Dyce Cay thought the Paper would be useful in directing attention to scour as the only natural agent for deepening and maintaining harbours on sandy coasts, and in demonstrating the impolicy of embanking estuaries. He was able to corroborate, from his experience at Aberdeen, the Author's statement, that when in such harbours depth had to be maintained by dredging, "every additional increase in depth thus attained increases in a sort of geometrical ratio the amount of material that has to be removed every year in order to maintain it." That result was indeed self-evident, as the increase must go on until the limit of the supply of silt had been reached. Mr. Dyce Cay.

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Mr. Dyce Cay. In cases, however, where sufficient scour could not be got, he thought much good might be done by stopping or diverting the sources of the inflow of silt into a harbour. From this point of view it appeared a mistake only to raise the jetties forming the sides of the entrance channel to half-tide level, as in the continental harbours described, and to allow the upper half of the tide, or littoral current, to flow freely over them, as in that state they formed groynes most favourable for collecting sand. On the other hand, when carried above high water, as in the case of the British harbours referred to, the tidal current was generally induced to run seawards along their sea face, which, with the help of the waves, prevented the advance of the low-water line outside them. The small river, which it was proposed to include in the new outer harbour at Boulogne, would also be a source of silt, and would thus cause expense in dredging. In the same connection, he considered that it would have been better if the new outlet of the Maas through the Hoek of Holland had been canalized with locks, like the Amsterdam canal, as in that way the silt, coming from the river and from the sand-bearing tidal sea water, would have been much diminished. At Dunkirk, which he had visited, the sandbanks, the channels of the sea, and the tidal currents, lay parallel to the coast. It seemed that an improvement might be possible by taking advantage of, and developing, this natural tendency, by means of jetties or other works parallel to the coast, similar to the outer part of the proposed enclosing piers at Boulogne. Such works might train a sea-current to run past the mouth of the harbour, and so by scour to effect the work of maintenance now done by dredging.

Commander Cialdi. Commander A. Cialdi approved generally the views of the Author as to the causes of silting-up of harbour entrances, and also as to the conservation and regulation of natural reservoirs for tidal water. But there were some points on which he differed from the propositions set forth in the Paper; as, for example, the depth to which wave-action extended, the Author estimating it at less than was, in his opinion, the case—and the life of closed harbours on sandy coasts. His own experience convinced him that jetty harbours were alone available under such conditions. His views on the subject were contained at length in his competitive essay for the prize offered by the King of the Belgians; but inasmuch as the international jury had not yet made its award he was prevented from enlarging upon them. The subject had for many years received his careful and attentive study, and it was with great pleasure that he found in the Author's communication

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confirmation of his own opinion, many times expressed, that hitherto the means employed for improving harbours on sandy coasts had not given satisfactory results. He considered that the Paper furnished a complete and just diagnosis of the case, although it left much to be desired in the direction of suggestions for affording a remedy. Commander Cialdi.

Mr. W. J. Doherty thought the Author had bestowed much care and devoted a good deal of attention to a subject which had frequently baffled engineers, and which had caused their plans to be altered almost as often as the sandbanks themselves. Every alteration or projection on a coast-line invariably affected the direction of the currents, and often, even without any artificial projections or indentations, large volumes of sand constantly changed their position, either on account of the more rapid flowing of spring tides, or the effects of periodical storms, which produced in shallow waters nothing but sand-bearing waves; hence the disturbed "equilibrium," attributed by the Author to artificial projections "from the coast," frequently resulted from purely natural causes. Mr. Doherty.

The statement that where a "current is checked by the construction of a jetty across the channel," a deposit in the channel was sure to follow, was a truism. Further, the lengthening of jetties seaward on a flat foreshore, if the jetties were in any part solidly constructed, acted as an obstruction or impediment to the flow of the littoral currents, and entailed as a sure consequence the extension of the beach. It did not seem surprising that jetty extensions were abandoned at Calais after 1845, and that the only effective remedy, the construction of a tidal reservoir or sluicing basin, was now in progress. Although, as shown by the Author, the opinion of Mr. Eyriaud-des-Vergnes at Dunkirk was against sluicing, it was because of the set of the tides; this, and every local circumstance, should be carefully examined and considered, before any remedy was decided upon. But it became serious when it required 350,000 cubic yards of dredging to keep open the channel, costing, as at Dunkirk, near £13,000 yearly.

A striking instance of local alterations in the shifting of sandbanks was at present noticeable in the Mersey at Liverpool, where the great landing-stage had become so affected during recent years by the movement of Pluckington bank, as to cause serious inconvenience from the grounding thereon of the stage, at extreme low water, thus interfering with the passenger traffic of the numerous ferry steamers, plying to and from the Cheshire side of the river. The engineer to the Mersey Board, Mr. Lyster, M. Inst. C.E., had

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Mr. Doherty. in progress an elaborate system of sluices, which were expected to deal effectively with the obstruction, although the cost would be considerable.

Increased depth of water at Dunkirk would seem to have produced similar results as elsewhere, viz., a rise in the tonnage, and increased size of vessels. On coast-lines, projections and embayments were frequently associated with encroachments and accumulations. The tide acting continuously on advanced headlands, carried with it the materials of which they were formed, and deposited it in the embayments as self-reclaiming foreshore. The rapid silting up of river-banks and estuaries by alluvial deposit-bearing rivers, when any impeding cause prevented their outward flow, was peculiarly observable during the construction by Sir John Hawkshaw of the Hull Docks in 1864, where 2 inches in depth of silt had been deposited in a single tide, on a portion of the site of the docks over which the ebb tide passed, and from which a clear flow could not escape owing to the progress of the river embankment. In this way in about eighteen months a depth of 15 feet of solid silt had accumulated.

The history of Ostend, from 1662 to 1744, instanced by the Author, was an example of the danger of closing up, or even temporarily allowing a diminution of the head of water required to keep open a channel, and showed that when once a harbour entrance was tampered with, it was next to impossible to restore it.

Numerous artificial channels placed at right angles to the coast-line had become deteriorated. A channel constructed by Mr. Doherty at Holywood in Belfast Lough in 1868, on a flat foreshore, where the sands were not much disturbed except in stormy weather, was rendered useless in a few years through silting up, no reservoir being available for scouring. At Silloth on the Solway estuary, the disaster to the dock caused it to be abandoned as a wet-dock, and the gates removed, converting it into a tidal basin. Progressive silting was the result, requiring considerable dredging.

The entrance channel to the harbour of Maryport, was a fair type of the jetty system, to be compared with some of the harbours brought under notice by the Author. With the exception of a small freshet, the Ellen, flowing through the harbour, the whole of the scouring force available to keep the channel clear of sand was that obtained from a small wet-dock from time to time. A solid stone pier had been constructed, from which was extended to low water a wooden structure of open work from half-tide. The gravel and sand accumulated behind the stone pier, as it was advanced. At present he was constructing, from the designs of

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Sir John Hawkshaw, Son, and Hayter, a large wet-dock and basin on the foreshore, adjoining and south of the stone pier. As the new works extended seawards, to the point of commencement of the timber structure, there was an apparent tendency of the gravel and shingle to collect in the angle formed by the junction of the sea embankment against the timber pier. However, the increased area, about 8 acres, of water space given to the harbour by the engineers, would largely augment the scouring power, so that, with a moderate extension of jetty, if required, a uniform depth of water might be maintained. Another example occurred at Workington, where the large quantity of shingle brought down by the Derwent, a river fed from the lake district producing a volume of water almost as great as the fresh water of the Thames, was barely sufficient to keep the channel clear, many of the projections and irregular deposits having to be removed and carried out to sea. Mr. Doherty.

Two of the Author's recommendations deserved attention. One was to extend the system of harbours where they existed, "supplying their own tidal reservoirs," as at Dublin; and the other was to avoid and discountenance "reclamation within the tidal area."

The history of all the harbours under consideration showed a neglect of properly curved training moles, walls, or half-tide erections, placed apart from, and at an angle sufficiently oblique to, the line of channel to enclose a large water space, by especially diverging and directing the flow of the latter half of the ebb, and causing a body of tidal water to act on the bars tending to form across the entrance to the harbour.

As a general summary, the regulation of harbours and of tidal waters by the State, under the guidance of the best qualified engineers, would appear to be a *sine quâ non*. Certainly no erections curtailing water space should be permitted without the consent and advice of a committee of the most experienced harbour engineers, as the protection and extension of commodious harbours should be the first duty of any great maritime power.

Mr. F. E. Duckham believed the objectionable features to which the Author referred, as existing in the new waterway through the Hoek of Holland, were recognised at an early date by Mr. Caland, and in 1877 the Dutch Government decided on spending half a million sterling in carrying out his recommendation, by straightening, widening, and deepening the channel between Maasluis and the sea. This involved the removal of some eight millions of yards of material, about one-third of which was to be dredged and Mr. Duckham.

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Mr. Duckham. dropped about 2 miles outside the piers, the remainder to be deposited on the adjacent dunes and polders, and in the little-used river Scheur. The then projected works in the river Maas had since been executed, but the cut at the Hoek of Holland had not obtained the width proposed by the plans of 1858. That width was to have been 750 to 850 metres (820 to 930 yards), but at present it was 500 metres (547 yards) only. A result of this was that the currents in the cut, and those above and below, were not in the right proportion, and the effect on the bar was not so beneficial as it would doubtless be when the full width was obtained. At present there were two channels, one along by the north and one near the head of the south pier. In both the depth was about the same, say 11 to 12 feet, at low water, but the south channel was much wider than the north. The works were still in progress, with proportionately increasing benefit to the navigation of the river.

The works at the mouth of the river Seine, including the Tancarville canal, had already been dealt with in the Proceedings,[1] so that it was unnecessary for him to do more than allude to them.

In reference to Ostend, Mr. Duckham did not understand that the sluicing basin was an entire success. It scoured a pit at its outfall, some 7 or 8 feet below the normal level of the harbour, but its useful effect seemed to be lost long before the water reached the harbour mouth, where its assistance was most required. As an improvement, a line of iron pipe had been laid down, more particularly to direct the sluicing force upon the bar; this was at first successful, but was subsequently rendered inoperative by the sand accumulating therein and completely choking the passage. It had recently been decided to endeavour to increase the depth at low water over the bar by dredging from 7 feet 6 inches to 12 feet, and to maintain that depth within the chief portion of the harbour by similar means. About 200,000 yards were dredged last year by a pair of sand-pumps on a dredger, having a steam-engine of 35 nominal HP. The spoil was deposited by hopper-barges on the Stroom Bank, some 3 miles from land. This machine could only work in comparatively smooth water, and no beneficial effect had been produced on the bar. The King of the Belgians had himself visited Ostend in the autumn of 1881, with the view to promote the improvement of the harbour, and it was expected that extensive operations would be undertaken at an early date.

The relative effects of wind, waves, and tides on foreshores were shown in the case of Gorleston beach, near Yarmouth Haven. The

[1] Minutes of Proceedings Inst. C.E., vol. lxix., p. 443; also *post*.

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ordinary run of the tides had little effect upon it, but a gale of a few hours' duration considerably altered its character, increasing or decreasing its extent according to the direction and force of the wind. Similar effects might be witnessed in other localities. Mr. Duckham.

Mr. J. P. GRIFFITH remarked that the Paper under discussion effectually refuted the doctrines advocated in that of last Session on "The Relative Value of Tidal and Upland Waters in maintaining Rivers, Estuaries, and Harbours."[1] From beginning to end the memoir formed a plea for the free admission of tidal water into harbours and estuaries. The history of almost every harbour and river referred to told of the injury resulting from the effects of land reclamation, and the consequent exclusion of tidal water. It was to be hoped that the discussion would solve some of the difficulties which surrounded this important subject, and explain why the jetty system, combined with sluicing, even on a large scale, had proved a failure. Mr. Griffith.

No one who had considered the subject of the improvement of the North Sea ports would deny the great difficulties which beset any work of the kind; nor would he fail to acknowledge the ingenuity and skill which had been displayed in the designs of many of the works executed for the improvement of some of the more important continental harbours. The leading features of these works were similar in nearly every one of the ports on that coast, viz., sluicing reservoirs, with jetties to concentrate the action of the scouring stream.

It appeared to Mr. Griffith that too much attention was paid to displacing the largest possible quantity of sand in the shortest possible time, without considering what was to become of that sand after it had been displaced. It seemed quite possible to have too great a velocity in the scouring stream, and the question was worth considering, To what extent was it desirable that the velocity of the scouring stream should exceed that of the littoral current into which it discharged? Sudden changes of velocity were, he believed, productive of much evil. Sluicing operations were generally carried on at low water, so as to produce the maximum results; and it was just at that time that the littoral currents were frequently least effective, and the incoming tide brought back much of the sand which had been displaced. He believed that too much attention could not be paid to an investigation of the fluctuations in direction and velocity of

[1] Minutes of Proceedings Inst. C.E., vol. lxvi., p. 1.

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Mr. Griffith. these littoral currents when considering the question of maintenance of harbour entrances on sandy shores. The system of parallel jetties so generally adopted at the North Sea ports, extending only to shallow depths, seemed to him wrong in principle. The tendency of such jetties was to act as groynes, and make the sandy shore extend outwards, until the sand passed round the pier-heads, when the waves heaped it up in the form of a bar. Extensions were made until the entrance was gradually removed too far from the sluices to be materially influenced by them; and, as a last resource, dredging beyond the piers was undertaken. This must ultimately prove a ruinously expensive remedy. One of the chief objections to the method just described was, that the entrance being placed in such shallow water the sandy bottom was influenced by every on-shore wind, and the temporary improvements resulting from either sluicing or dredging were neutralised, if not destroyed, by a few hours of stormy weather. From a natural anxiety to utilise to its full extent the available sluicing power, the channel between the jetties had frequently been made so narrow that the navigation of vessels entering the port was very difficult, especially where a strong littoral current existed. To obviate this in some degree, jetties were sometimes made slightly diverging, as in the case of the last extension at Ostend. This diverging form was accompanied by the serious objection that it tended to increase the height of the waves running up the channel. If converging piers had been adopted at the mouth of the Maas, as might have been done without much extra cost, greater shelter would have been given to the new channel through The Hoek, the waves entering being reduced by dispersion. There was little doubt that the Author was correct in his opinion that the economy practised in not excavating the new channel sufficiently wide in the first instance had resulted in much injury to the entrance.

Perhaps the most interesting part of the Paper was that relating to the coast of Belgium. Much attention had been given of late years to the question of the improvement of the ports on that coast; and if any need existed to prove the difficulty of constructing first-class ports on the coast of Belgium, no more convincing evidence could be brought forward than that the principal port of the country was situated about 40 miles up a river difficult to navigate, and which for the greater part of that distance ran through a foreign country. Such was the position of Antwerp on the Scheldt, the most flourishing and important port of Belgium. Both banks of the river for 30 miles from the

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mouth were in Holland, so that in case of war between the two countries there would be little difficulty in blockading the port, and almost putting a stop to the maritime commerce of the country. It was not therefore to be wondered at that there should be a general desire to improve the coast ports. How this could best be done was worthy of consideration, and though the difficulties were great, yet Mr. Griffith was inclined to look hopefully at the prospect of improvement. It was well to bear in mind that the Port of Dublin had at one time greater difficulties in the way of becoming a first-class port than any of the ports on the Belgian coast had to encounter at the present day. The tidal estuary of the Scheldt, he believed, played an important part in protecting the Belgian coast from the accumulation of sandbanks, and accounted for deep water approaching the shore near Blankenberghe. It would be well for the Belgian authorities to take to heart the warnings contained in the Paper, and to resist any proposals to regulate the Scheldt which might tend to reduce its tidal capacity, not only for the sake of the port of Antwerp, but also for the protection of the ports on the coast of Belgium. The maritime frontier of Belgium was 42 miles in length, or only one-twentieth part of the whole frontier of the kingdom. Limited as was this coast-line, it presented many obstacles to the formation and maintenance of first-class ports. It formed an almost unbroken straight line destitute of estuaries or bays, the shore being generally low and formed entirely of sand with a gradual slope. Deep water was only reached at considerable distances from land except near the Dutch frontier, and shallow banks generally cut off direct communication with the shore for vessels of even moderate draught, except at or near high water. These shoals, known as the Flemish Banks, formed the great obstacle to navigation in those regions, and they extended almost from the Straits of Dover to the mouth of the Scheldt. Their general direction was parallel to the land with intervening channels of considerable depth, but intricate and dangerous to navigate. The rise and fall of the tide amounted to 17 feet at springs, and 11 feet at neaps; but this was materially modified by the direction and force of the wind as well as by barometric pressure. The directions of the tidal currents off the coast of Belgium were specially remarkable. At high and low water the direction of the current was parallel to the shore, or nearly east and west. At half flood its direction was on-shore, and at half ebb off-shore. This was no doubt in a large measure due to the great tidal estuary of the Scheldt, into which the flood tide set for several hours after the

Mr. Griffith.

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Mr. Griffith. time of high water at its mouth, while the ebb in like manner continued to flow outwards long after the hour of low water on the coast. The ports on the coast were but three: Ostend, Nieuport, and Blankenberghe. All were tidal harbours with shallow approaches, Nieuport and Blankenberghe being almost exclusively devoted to fishing-boats or vessels of the smallest class. Ostend possessed a large harbour with extensive basins and quays, and great facilities for further dock extension should it be required. A large fishing fleet frequented the port, but Ostend owed most of its importance to the daily mail packet service with England. Of late years the number of passengers carried by this service had shown a steady diminution, due no doubt to the opening of new routes or the improvement of existing services. Unless vigorous steps were taken, a further falling-off must be expected. Much had been done in the hope of improving the port, but without any considerable success. The result of the costly work described in the Paper for the improvement of Ostend could not be regarded as satisfactory. The channel was still shallow and encumbered by sand blown in from the adjoining beach or driven in by the sea, while the bar, a short distance beyond the pier-heads, still formed a dangerous obstruction. No doubt the depth of water over it was from time to time increased by the large volume of water suddenly thrown on it from the sluices, but the next sea-breeze raised waves sufficiently powerful to destroy all the good effects, and the uncertainty of depth at the entrance during on-shore winds practically neutralised the useful effects of the sluices. Depth of water at the entrance to a port was more needful during stormy than in calm weather, and it was just at such times that sluicing operations, similar to those at Ostend, failed. It might be argued that in this particular case not much would be gained by a great increase in depth of water on the bar, as it was in fact rather the Stroom Bank, extending from Nieuport till it joined the shore some distance east of Ostend, which obstructed direct communication with the sea.

From this brief description it would be seen that the present condition of the Belgian ports was anything but satisfactory. What, then, was the remedy? The extent of sea-coast being so limited, he believed that all efforts should be concentrated on the formation of one first-class harbour which would supply the following wants: 1st. A port open to vessels of large draught at all states of the tide. 2nd. A naval station. 3rd. A harbour of refuge. The entrance of such a harbour must be placed in deep water, and in such a position that there might be no difficulty in maintaining

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the required depth. Bays or estuaries on a coast materially facili- Mr. Griffith.
tated the construction of harbours, and to estuaries or bays England owed much of the success of some of its largest ports. On the Belgian coast no such natural advantages existed, and it was necessary to enclose the required area artificially. The question of site was one of the most important considerations. Practically there were but four sites worthy of discussion, viz., Nieuport, Ostend, Blankenberghe, and Heyst. The two latter were among the most favoured sites on the coast for the formation of a deep-water harbour, and no doubt a most useful harbour could be constructed at either of those places at a comparatively small cost. At the same time all the necessary accessories of a first-rate port would have to be added, as none at present existed. Nieuport laboured under similar disadvantages without any redeeming features. Mr. Griffith believed Ostend to be the most eligible site for such a harbour, and he thought all efforts should be concentrated there, although the expenditure might at first sight seem large. Among the many advantages which Ostend possessed over the other sites named, the principal was its being already an important port. Its docks and quays were extensive, and it was amply provided with means of communication with the interior of Belgium both by canals and by railways. It was also the packet station of the English mails. Blankenberghe and Heyst would require a large expenditure on quay and dock accommodation in addition to the cost of a harbour, while the existing interests of Ostend would be materially injured. For these reasons, although the apparent first cost of constructing a suitable harbour elsewhere might be less, yet indirectly a much larger expenditure would be involved. The great difficulty in the formation of a deep-water harbour at Ostend, open at all states of the tide, was the presence of the Stroom Bank, situated about a mile from the shore. No doubt a harbour could be constructed, with its entrance in the Inner Road, which would materially improve the depth of water on this bank, by the joint action of the littoral currents and those entering and leaving the harbour, as in the case of the improvement of the bar of Dublin Harbour. Such improvement would, however, be very gradual, and he was in favour of adopting a plan which, if bolder and more costly, would give more rapid and certain results. With this object he would propose the construction of two great piers extending out at right angles to the shore line till they reached depths of about 3½ fathoms outside the Stroom Bank; they would then converge in a direction nearly parallel to the coast, leaving an opening not less than 1,000 feet wide between the pier-heads,

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Mr. Griffith. The object of extending the piers to the outer edge of the Stroom Bank was twofold. In the first instance, to place the harbour entrance in such a position that it would be within the influence of the tidal stream ebbing from and flowing into the estuary of the Scheldt, which at present maintained deep water outside the Stroom Bank. The direction of the extreme portions of the piers being almost parallel to the coast would least interfere with its action, and it might reasonably be expected that the projection of the piers so far seaward would tend to intensify its effect. In the second place, the shelter afforded by the extension of the piers beyond the Stroom Bank would allow of dredging that portion of the bank which was enclosed within the piers, an operation otherwise practically impossible, and even if possible of very doubtful utility without the shelter of the piers. Such a harbour would necessitate the construction of piers of an aggregate length of about 22,000 feet. The improvement of the entrance to Dublin Harbour had involved the formation of more than 26,000 feet of piers. Although an expenditure of about £2,500,000 might be necessary, Mr. Griffith believed it would be fully warranted on the grounds of the national importance of the undertaking.

Mr. Keller. Mr. H. KELLER agreed on the whole with the conclusions arrived at by the Author; but he was of opinion that the latter attached too much importance to the action of the ebb tide on a harbour; for harbour basins invariably contained less tidal water than the estuaries of rivers, and as their extent was much less, their ebb was proportionably weaker. Harbour basins would have to be greatly enlarged if the ebb tide were to be made sufficiently powerful to scour the entrance thoroughly and effectually, as it certainly was in estuaries. It might be safely accepted, that wherever the conditions for the formation of bars were present, sooner or later, the entrance of the harbour would be barred, however far the moles might have been extended. The most favourable condition for the formation of bars was the presence of a littoral current (arising from prevalent winds, and influenced by the tidal wave), which kept the particles of sand in a state of intermittent motion. The harbour of Kingstown was most fortunately situated in this respect; there were no travelling sands at the south coast of the Bay of Dublin. Boulogne also enjoyed an exceptionally good position; for the shore sloped down in terraces, and the coast was not a flat sand coast, but consisted of rocks, the cavities of which were filled with sand.

At Ymuiden a change in the shore was already becoming observable, and the bar which was forming at the mouth required

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considerable dredging only a few years after the completion of the harbour, to maintain the necessary depth of water. If such dredging was to be avoided artificial scouring must be called in aid, and this would only then prove effectual when the sluices were constructed in the vicinity of the mouth of the harbour. Further, it was imperative that the flushing water should not be permitted to discharge suddenly, but be distributed over a period of some time. By such means the dangerous rapidity of flushing would be prevented, and the scour, though less violent, would exercise a more lasting and beneficial influence. With due attention to local circumstances, it would be desirable to wash the sand away immediately after it had been deposited on the bar, and when it was still easily removable. To this end a portion of the harbour basin should be separated as a flushing basin by a third "inner" mole. With a view to reduce the force of the waves in the harbour at high water, this inner mole should be constructed as an open frame jetty, capable of being closed as soon as ebb tide set in. Mr. Keller.

Lieut. L. PETIT, of the Belgian Hydrographic Service, begged to present to the Library a copy of his report on the changes of the North Sea coast during the present century. He was firmly of opinion that the ports of Calais, Dunkirk, Nieuport, Ostend, and Blankenberghe represented the type best adapted for the littoral between Calais and the Scheldt. The trestle piers had been constructed on principles approved by long experience of the regimen of the coast, and which nothing of recent occurrence had tended to modify. The existence of those ports would be endangered by the introduction of novelties, such as lengthening the piers or widening their entrances. In the first case the foreshore would follow the prolongation. Dunkirk presented a striking instance of the danger of having piers too long. In the second case, if the entry were made too wide, banks would form inside, which after heavy weather would seriously compromise the navigation. In his opinion, the only possible solution unattended with danger was the establishment of works parallel with the coast line, provided always that they were sufficiently far from low-water mark. In this way he thought that the project to construct a breakwater in front of Ostend (a plan three-quarters of a century old), far from being injurious to the little roadstead, could only result in its benefit, by contracting the flood-tide between the coast and the breakwater. Trestle piers should only be of the length practically necessary. The ends of the trestles should not be embedded in stone mounds, as that encouraged sand and facilitated the formation Lieut. Petit.

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Lieut. Petit. of bars. The two piers could not be parallel for their whole length; they should be funnel-shaped, the greatest width at the mouth, gradually lessening to a certain limit within. The axis of the entrance channel should in direction be north-west and south-east, or even west-north-west for the western pier, if possible, so as to avoid an entrance perpendicular to the coast, which was always objectionable. This oblique direction facilitated the entry to the port. Vessels of a certain draught of water could only come in on the flood, and a rather long vessel when entering was subjected to a stronger tide on the starboard quarter than on the starboard bow already within their protection. This tended to swing it across the channel, especially if there was a strong west or north-west wind. This danger could be notably lessened by giving a north-west, or west-north-west direction to the channel. The ship, whether a steamer or a sailing vessel, could then come in with the wind astern, and cross the current obliquely. The western pier should be longer than the eastern, in order to slacken the strength of the flood, give shelter in bad weather, and permit outgoing vessels with light breezes to clear the eastern pier. With north-east winds they could also easily get out under sail. The only possible sea-works were those parallel with the coast, for they would not interfere with currents taking the same direction when at their greatest force. Such were, in his opinion, the essential conditions to be borne in mind in regard to the Belgian coast. Trestle elongations, spreading out from the existing piers, would only result in the formation of reservoirs of sand and silt, the removal of which would more than counterbalance the services the piers would offer to navigation.

Mr. Pettit Mr. PETTIT wished to remove some slight misapprehension under which the Author appeared to labour with respect to the jetties of the Adour. In the first place, the existing iron cylinders did not date from 1859, but from 1867. They replaced an open trestle structure put up at the earlier date, but which had soon been destroyed by the teredo. It had been hoped to apply the principle of placing movable panels between the cylinders, so as to have at will either open or closed jetties. But these panels, cumbrous and difficult to manage, had never been put in place, and up to the present time they had had to content themselves with skeleton structures. It should be stated that the cylinders were connected at the bottom by continuous rubble mounds, rising to within 6½ feet of low water.

In the second place, although it was undoubtedly true that the tidal oscillation was greater in the open sea beyond the bar than

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in the river,[1] this could not be attributed to the jetties. Their distance apart, 170 metres (say 560 feet), which depended on some works executed in 1743, appeared to be sufficient; and, indeed, there might be noted on the plan he had furnished to the Author, a bank of sand advancing through the open work of the northern jetty, opposite the signal-tower, to a distance of 230 to 260 feet. This was just where the width of the mouth was least, being often reduced to 90 or 100 metres, and it was this bank which dammed the water of the river at low tide, and conversely arrested the free flow of the tidal water on the flood. If the distance between the jetties was greater the result would be the same. Mr. Pettit.

He was in accord with the Author in the view that the effect of the works on the depth of the channel had been but moderate. Solid jetties appeared to have a prejudicial influence in arresting the sand and advancing the foreshore, and the bar. In his opinion the only certain benefit had been the regulation of the channel at the mouth. Before the construction of the works the Adour shifted about on the coast; from 1500 to 1578 its outfall was 36 kilometres to the north of the present channel; towards 1730, 2 kilometres to the south. At present the channel was fixed by the jetties, and could only vary within the limits of the 170 metres separating them. It was expected that by lengthening the cylinder jetties by 150 metres, so as to reach the highest point of the bar, matters would be mended; but though he himself hoped for this result, he was not sanguine. The extension had, however, been gazetted of public utility, and the works would be begun in the approaching summer.

To deepen the channel of the Adour flood water was required, for, contrary to the theory of Mr. Caland (referring possibly more to the interior of rivers than to bars), it was found that heavy floods had most effect on the bar. After such a downflow of fresh water they sometimes had 3 and even 4 metres in the channel at low water, and the sand-bank on the northern side was reduced, or disappeared altogether. On the other hand, the occurrence of ocean storms, with low tides, would reduce the depth to from 2 to 1½ metres, or even to 1·2 metre (4 feet). The bar had even been known to emerge above low water, thus entirely closing the space between the jetties. In that case the water escaped through the spaces between the columns. Generally, however, after two or three days of fine weather the channel opened afresh.

[1] At spring tides the rise and fall outside the jetties was 4 metres; in the Adour it varied from 2½ to 3 metres.

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Messrs. Plocq and Guillain.

Mr. PLOCQ, Inspector-General of the Ponts et Chaussées (formerly Engineer-in-Chief of the harbours of Dunkirk and Gravelines, and subsequently of Boulogne and Calais), and Mr. GUILLAIN, Engineer-in-Chief of the harbours of Boulogne and Calais (formerly engineer of Dunkirk harbour), considered it specially necessary to indicate certain local conditions which appeared to them essential for the thorough comprehension of the different efficiency of the same methods of improvement adopted in various harbours on sandy coasts. With respect to Boulogne harbour, the chart of the French coast near the Straits of Dover showed that the shore, which was sandy between the estuaries of the little rivers Somme, Authie and Canche, changed to a high cliff north of the Canche, consisting of alternate layers of clay and rock. The cliff ran north and south up to Cape Alpreck, about 2 miles south of Boulogne; then it turned eastwards in a curve concave towards the sea, and approached the meridian of Alpreck again near Cape Grisnez. The size of this curve was 1 mile, and its chord 10 miles long. About 1½ mile to 2 miles from the line of the cliffs there existed a sand-bank, more than 12 miles long, pointing approximately N. ¼ N.E. The top of this bank, called the Bassure de Baas, was on the average 26¼ to 29½ feet below low-water; whilst the adjacent depths, out at sea and between the Bassure and the coast, averaged from 59 to 66 feet. The flood and ebb tidal currents, alternately flowing nearly from south to north, and from north to south, had sufficient strength between the Bassure de Baas and the shore to prevent any deposit of sand over a width of about 1½ mile, measured from the inner foot of the Bassure. Over all this expanse the clayey or rocky bed was laid bare, only shingle or coarse gravel being able to rest in the hollows of the bottom. This strip of hard bottom, kept constantly scoured, extended as far as the rocks at the foot of the cliff to the right of Cape Alpreck, and of the portion of the cliff which continued about 2 miles south of this cape: in this region, in fact, the principal currents between the Bassure and the shore were concentrated within a width of only 1½ mile. In consequence, however, of the expansion of the current produced by the concavity of the coast to the north of Cape Alpreck, the velocity of the current diminished near the shore in front of Boulogne, and beaches of sand existed at the foot of the cliffs on each side of the harbour jetties. The sand, however, only formed a thin layer, over the bed of clay or rock, which diminished in thickness as it approached depths of from 20 to 23 feet below low water, and disappeared when depths of 23 to 26 feet were reached. The plan (Plate 2, Fig. 2), showed that the outer breakwater of the new

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harbour would be similarly situated, in respect to the removal of the sand by the tidal currents, as the rocks at the foot of Cape Alpreck; and it was difficult to see how sand could remain there. It was probable that the triangular recess between the south-west breakwater and Cape Alpreck would silt up. It might, however, be hoped that this accumulation of sand would not affect the depth at the foot of the outer breakwater; first, on account of the erosive action of the currents, which would arrest the advance of the sand before it attained the meridian of Alpreck or the angle of the breakwater; secondly, on account of the action of the waves which, breaking in this angle during storms with great violence, would take out to sea a large part of the sand which had been deposited in calm weather. The deposits also of sand inside the harbour, when completed, did not appear likely to exceed the practical limits of regular maintenance by ordinary dredging, considering that it had been proved that the quantity of sand held in suspension by the sea in all states of weather in front of Boulogne was not very large. Accordingly the site of the new harbour was characterised by specially favourable circumstances; first, very strong alternating flood and ebb tide currents, which had already laid bare the clay and rock at the bottom of the sea in front of the side of the breakwaters; secondly, on the south side, whence the flood-tide came, a length of nearly 2 miles of rocky cliffs, whose base was scoured by the currents, and which separated Boulogne from the great sandy beaches of Picardy; thirdly, the possibility of constructing the harbour in a bend of the coast, without any marked projection from the line of these cliffs, and consequently without risk of altering the flow of the currents between the coast and the Bassure de Baas. Under these circumstances the new harbour of Boulogne presented no similarity to sandy harbours, such as those on the south coast of the North Sea; and serious failures might occur if, in the event of the success of the Boulogne works, it was attempted to apply the same system for forming roadsteads in front of the harbours on the south coast of the North Sea. The jetty channel of Boulogne, situated in the centre of the sandy bay, was in reality a sandy harbour, but it differed from those on the North Sea coast, owing to the much greater agitation of the sea at Boulogne. Artificial sluices had been used, since the silting up of the Liane estuary, for maintaining a channel across the sandy beach which extended out in front of the Boulogne jetties, but they were always too feeble; this, however, would not be so if the Liane estuary could be restored to its original capacity. Since October 1881, dredgings of sand had been commenced outside the jetties, in order

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to maintain a channel with a depth of 5 feet below the lowest tides, which was the depth requisite for enabling the Folkestone and Boulogne steamers, drawing 8½ feet of water, to enter at fixed times. These dredgings were performed by sand-pumps, as at Calais and at Dunkirk, which could continue working in waves from 2 to 3 feet high. During two hundred and twenty-seven days, from the 15th of October 1881, to the end of May 1882, the dredging could be carried on, outside the jetties, for six hundred and eighty-one hours, spread over ninety-two days; thus bad weather and repairs stopped the work for three-fifths of the whole period. At Calais, where the sea was less rough, the coefficient of interruption was only one-half, and at Dunkirk only $\frac{1}{2 \cdot 25}$. The dredgings at Boulogne were conducted by a contractor, with his own plant, at a price of 11·3*d.* per cubic yard dredged and conveyed 1 mile out to sea. From the experience of the first seven months, the cost price was 9·3*d.* per cubic yard, including solely labour, fuel, repairs, and maintenance. The cost would diminish in the future, as occurred at Dunkirk, in proportion as the depth increased, enabling the work to be carried on during low tide. Hitherto 82,500 cubic yards had been dredged, and already an increase in depth had been observed.

With respect to the harbours on the southern coast of the North Sea, all the French ports of the North Sea opened on to nearly flat and very extensive beaches of sand. As the flood-tide coming from the west was the strongest, and the south-west to west winds were the most frequent, the direct action of the wind on the dried sands of the beach, and the combined action of the currents and wind, caused a definite travel of sand towards the east along the coast, though this motion was arrested during the prevalence of east winds. Every solid jetty, connected with the shore and forming a transverse groyne, was necessarily sooner or later overtopped near the land, and outflanked at its outer end, by the sand travelling along the coast. The effect of storms was to raise the level of the bottom where the waves broke, as observed at Calais and at Dunkirk. After each violent storm the low-water mark tended to advance in the harbour channel at the outlet of the jetties, towards the west with westerly storms, and to the east with easterly storms, without generally affecting the outer channel further out; the inroad of sand being thus nearly always confined to within 200 or 300 yards from the head of the jetties. The storms, moreover, brought a large quantity of sand (sometimes 25,000 to 40,000 cubic yards in a few days), through the open timberwork jetties into the inner

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channel at the foot of the windward jetty. This sand was mostly blown in by the wind from the dry beach at low water, and some also was brought in by the waves which, having passed through the jetty at high tide, deposited in the comparatively calm channel a large portion of the sand held in suspension. Another circumstance, common to these ports and peculiar to them, gave rise to arrangements which would not be equally applicable elsewhere, namely the function which these ports discharged in draining the country, whose general level was below high water. The drainage waters had to be provided at these ports with outlets and sluices, which, retaining them at high tide, ensured their discharge between half-ebb and half-flood tide. Messrs. Plocq and Guillain.

There was a certain difference in the nature of the drainage waters discharging at the ports of Calais and Dunkirk. At Dunkirk the waters were much more muddy than at Calais. Carried towards the west along the shore (owing to the line of outer banks which formed the Dunkirk roadstead) by the ebb tide, at which period the discharge always took place, the waters deposited a portion of their mud on the strand during the flood tide, when the current turned towards the south before resuming an easterly course. In consequence the upper portions of the beach were silty, and the lower and submerged portions, both to the west and in front of the port, were composed of sand mixed with silt; whilst to the east the sand was nearly pure. Moreover, the water in the channel between the jetties at Dunkirk contained a large amount of mud at the time of the filling of the harbour, which, forced back by the tide, was deposited in the interior. At Calais, on the contrary, the drainage waters were carried further out at sea (owing to there being no roadstead parallel to the shore); the interior of the harbour silted up but little, and the sands in front of the harbour, as well as on the east and west strands, were almost pure. Besides, it must be observed that, in front of Dunkirk, the five lines of sandbanks which stretched parallel to the coast broke the sea outside and maintained a comparative calm, even during heavy storms, in the deep water which formed the Dunkirk roads between the first line of these banks and the shore; whereas Calais, having only the low and narrow bank "du Riden" in front of it, was exposed to storms from the open sea, though much less violent than in the region south of Grisnez. Lastly Calais, being situated very near the Straits, had very strong currents passing by the ends of its jetties; whereas the currents were much weaker in the Dunkirk roads. These different conditions explained—first, the different configuration of the strands on each side of these two

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Messrs. Plocq and Guillain.

ports; secondly, the different efficiency of the same methods employed for maintaining the depths at these ports. At Calais the sand of the west beach, not being rendered coherent by silt, was easily carried eastwards by the winds and currents, and was readily put in suspension by the waves, so that sand accumulated as much on the east side of the port as on the west; moreover, the shelter afforded to the east by the jetties from the prevalent westerly storms favoured the deposit of sand on that side. The results were—first, that the low-water mark on each side of the port followed a straight line, nearly perpendicular to the line of the jetties, which inclined towards the west at an angle of 67° to the coast line; secondly, that the eastern beach was even larger than the western; thirdly, that easterly winds tended to fill up the entrance with sand quite as much as westerly winds. At Dunkirk the silty western beach retained a portion of the sand travelling from the west, and tended to advance; whereas, on the contrary, the eastern beach was concave for some little distance from the eastern jetty, and the low-water mark approached and remained nearer the land. The results were—first, that the low-water line on the west side, near the port, continued for some distance parallel to the line of the west jetty, which, however, made a larger angle with the general line of coast than at Calais (79° instead of 67°), whereas the low-water line to the east diverged at once from the line of the jetty channel; secondly, that the westerly storms were the most prejudicial in silting up the entrance, whereas the easterly storms, by turning back the sand of the western beach, did more good than harm.

In front of both harbours the bed of the sea, below low water, descended with a gentle inclination to a depth of 10 to 13 feet, then with a more rapid slope to the great depths of 50 to 65 feet. Owing, however, to the difference in the strength of the tidal currents and in the force of the waves, the slope of the great depths was only 1,150 to 1,300 feet from the end of the Calais jetties, whereas it was from 2,000 to 2,300 feet away from the Dunkirk jetties. It was shown in the Paper that very nearly the same methods had been adopted at the two harbours for obtaining a suitable depth at the entrance and inside.

The prolongation of the jetties should follow the natural progression of the strands, but should not outstrip it, for not only did hasty extensions produce no permanent improvement in depth, but they, moreover, hastened the increase in the depth of sand from whence the winds and waves took the materials which they deposited between and in front of the jetties.

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The formation of these harbours was due to sluicing, which had been gradually developed as a means of deepening, all the less costly because the works had been, and always were, in a great measure necessary for the drainage of the district. Messrs. Plocq and Guillain.

At Calais, with an average discharge of 450 cubic yards per second, lasting with efficiency from one-half to three-quarters of an hour, the sluices had procured—first, in the channel between the jetties, a depth of 5 feet 9 inches to 8 feet 2 inches below the zero of the charts (zero being the lowest tides known); secondly, outside the jetties, for a width of 130 feet, a minimum depth which varied, according to the frequency of the storms, from 10 inches to 4 feet below zero, the direction of the external channel being slightly inclined to the east of the line of the jetty channel. For improving the harbour still more, and for admitting the mail steamers of greatest draught at low tide, a new sluicing basin of 235 acres was projected in 1875, and commenced in 1880 on the upper part of the east beach. This basin would increase the discharge of the sluices from 450 cubic yards per second (as at present) to more than 1,100 cubic yards, the effective period of sluicing remaining the same.

At Dunkirk, with an average discharge of 510 cubic yards per second, having an efficient duration of about three-quarters of an hour, the sluices gave: (1) in the inner channel, the same depth as at Calais below zero; (2) outside the jetties, over a width of 100 feet, a minimum depth varying from the zero to 2½ feet below, according to the weather. When the working of the sluices was stopped for some time for repairs the entrance channel gradually shoaled, the bottom having risen to 2½ feet above zero. For a long time the external channel of Dunkirk harbour was almost always deflected to the east, at an angle of 20° to 30° to the prolongation of the line of the jetty channel. This deviation was due to the tendency of the west beach to encroach on the channel. It was in order to bring back the external channel to the line of the inner channel that Mr. Plocq employed, from 1865 to 1877, the system of movable jetty mentioned by the Author. This floating movable jetty, formed of thirty guide frames, each 33 feet long, fastened end to end, was stranded in prolongation of the east jetty in very fine weather, and the sluicing current, thus guided, scoured out a channel in the line of the jetty channel; and this improvement in direction usually lasted till the next severe westerly storm occurred. Ten of these operations in the year sufficed to maintain the entrance channel in a fairly good direction. Thanks to these means, the Port of Dunkirk had usually a depth

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Messrs. Plocq and Guillain.

at high water, in the entrance channel, of 20 to 21½ feet during ordinary spring tides, and 16½ to 18 feet at neaps. This depth being inadequate, Mr. Plocq proposed in 1861, and adopted in 1865–70, a new series of sluicing basins, which would raise the average discharge of the sluices to 1,070 cubic yards per second. This arrangement was to accomplish three objects of equal importance: (1) the military defence of the place; (2) the improved drainage of 111,200 acres of low lands, discharging their waters at low tide through Dunkirk; (3) an increase in the sluicing power. This was following out Vauban's principles, who, in the seventeenth century, had organised in this way the ports and fortified places of French Flanders. As the drainage waters had only an intermittent flow into the sea at low tide, it was a great advantage to provide great reservoirs near the sea, into which they could flow and be stored up whilst the high tide prevented their flowing into the sea. For this purpose it was only necessary to connect the upper ends of the sluicing basins with the drainage canals, closing the communication by protecting sluices provided with sea gates. In this way the sluicing basins would act as reservoirs for land floods, and the scouring sluices for the discharge of the fresh waters; and then, when it was not necessary to let out the fresh waters at once, the gates of the protecting sluice had only to be closed to allow the basins to be filled at high tide with salt water, which could be used for scouring the channel at low tide. The ditches of the new fortifications (rendered necessary by the extension of the port) had been made 165 to 230 feet wide, so as to serve both as reservoirs for the fresh waters and sluicing basins of salt water, whilst being improved as defensive works; and thus an improved means of drainage, and new sluicing basins, had been obtained at a cost which would have been reasonable for either object, and a large portion of which was necessary for defence. The two new scouring sluices, having a total width of opening of 100 feet, at the outlets of the east and west trenches respectively, for emptying reservoirs having an area of 163 acres, were completed, and had served for some time to discharge the fresh waters, but the reservoirs were not quite finished.

The new sluicing basins at Calais and Dunkirk would in all probability increase the depth of the channel between the jetties to 13 or 16½ feet. The scouring current, whose efficiency rapidly decreased on leaving the jetty channel, also readily removed the sand, brought in by storms, from the channel for 300 to 600 feet beyond the jetties; but there would remain, between the deep

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inner channel and deep water outside, a more or less elevated plateau which sluicing could not lower. It was probable that the increased sluicing power would not procure a depth of more than 6½ to 8¼ feet below zero over this plateau either at Dunkirk or at Calais. But in order that a vessel drawing 23 feet of water might enter Dunkirk harbour at high water neap tides, with at least 20 inches of water under its keel even in rough weather, it would be necessary for the inner channel to be at least 10 feet below zero, and the outer channel 11½ feet below. Vessels of that size could enter Calais in all weathers at high water without any improvement being needed, as the range of tide was more than 3¼ feet greater at Calais than at Dunkirk. Calais, however, was a mail-packet harbour, and as it would be desirable that mail-boats drawing 14¾ feet should be able to enter at low water neap tides, the inner channel should be 13 feet, and the outer channel 14¾ to 16½ feet below zero. Though the sluicing basins in course of construction would probably procure the desired depth in the inner channel, and near the head of the jetties, at both ports, they would certainly not give a sufficient depth in the outer channel. The Government accordingly decided, in 1875, by the advice of Mr. Plocq, to assist the deepening of the outer channel at Dunkirk by dredging. As the result was satisfactory, the same engineer proposed, in 1881, and obtained permission, to dredge the outer channel at Calais. The success of the dredging operations at Dunkirk and at Calais was entirely due to the employment of sand-pumps, with flexible tubes, placed on screw steam hopper-barges, which conveyed the material to the place of deposit. These machines possessed the advantage of working easily in a moderate swell (from 1 foot to 2 and even 3 feet); of not being liable to damage from the swell; of being held in working by a single anchor, and therefore able to start work in a few minutes; and, lastly, of not impeding the entrance of the harbour with their moorings and with separate barges.

Messrs. Plocq and Guillain.

Between February 1876 and the 1st of May, 1882, 955,000 cubic yards of sand had been dredged beyond the Dunkirk jetties, of which amount about 490,500 cubic yards had been removed during the year ending the 1st of May, 1882. Although the new sluicing arrangements were not yet in operation, and the working even of the old sluicing basins had been considerably reduced by reason of the new dock works, which diminished their area, the smallest depth in the outer pass was 5 feet 9 inches below zero in May 1882, making an increase of 3¼ feet beyond the greatest depth obtained by the sluices alone. The greater portion of the raised plateau, from

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1,600 to 2,000 feet wide, which formerly separated the deep inner channel from the roadstead, had been deepened to more than 8½ feet below zero, and was therefore on the average more than 6½ feet below its old level. Moreover, the pass had been now considerably extended on both sides, and it was being still further enlarged towards the west, to prevent the sudden encroachments of the west beach during storms from reaching the navigation channel. Work was commenced with one dredger, which was improved as experience dictated; the number had been from time to time increased, and since March 1882 four sand-pump hopper-dredgers had been at work, their total strength being 560 I.HP., and their hoppers having a total capacity of 1,023 cubic yards. These four dredgers removed 52,300 cubic yards of material, measured in the hoppers, in one month of average work, and conveyed it 2½ miles out to sea. The work was done by contractors, who owned the plant. The contract price in 1875 was 21·1*d.* per cubic yard, dredged and conveyed away; but subsequently the price was reduced to 11·6*d.* in 1880, 10·2*d.* in 1881, and 8·7*d.* in 1882. The cost price, exclusive of insurance, depreciation, interest on plant, and profit, had been regularly decreasing, owing to successive improvements in construction and working, and also because the increased depth already obtained had now admitted of almost continuous working, whereas at the commencement the work could only be carried on during the higher half of the tide. This cost price, including wages, fuel, maintenance, and repairs, had exceeded 7·3*d.* per cubic yard up to 1880; since then it had regularly diminished, and appeared now to amount to about 2·9*d.*

The dredging at Calais were only commenced on the 20th of June, 1881. Already in less than a year, an improvement had been effected nearly as great as at Dunkirk, with much less plant and less expense. Profiting by the experience gained at Dunkirk, dredging was commenced at Calais with three sand-pump dredgers, one a hopper-dredger and two not, and now the work was being continued with a single sand-pump hopper-dredger. The three dredgers had removed 180,500 cubic yards of material in the five months ending November 1881. The hopper-dredger, which had been working alone since December 1881, a screw-steamer of 120 I.HP., holding 220 cubic yards of sand, and furnished with a rotatory pump capable of discharging 1,300 cubic yards of water per hour, had removed 107,200 cubic yards in the six months ending May 1882; making a total amount of 287,700 cubic yards in eleven months (Fig. 2). Now the outer channel, at the end of

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May 1882, had a minimum depth of 6¼ feet below zero, which was more by 2 feet than the greatest depth ever previously attained, for a brief period, by the sluices alone. The plateau also, which formerly extended between the inner channel and the roadstead, had been lowered, on the average, to more than 7¼ feet below zero, or more than 5 feet below its original level. The price to be paid for the future to the contractor, as arranged in February 1882, was 6·55*d.* per cubic yard, measured in the hopper, dredged and conveyed 1 mile out to sea with his own plant. The expenditure on wages, fuel, maintenance, and repairs, in dredging 66,831 cubic yards, during the first four months of 1882, amounted to £844 13*s.*, giving a cost price of 3·03*d.* per cubic yard.[1] The dredging at Calais had produced a more rapid improvement than at Dunkirk, for the following reasons: first, the sand, being purer, was drawn up with the water by the pumps more readily, and in larger quan-

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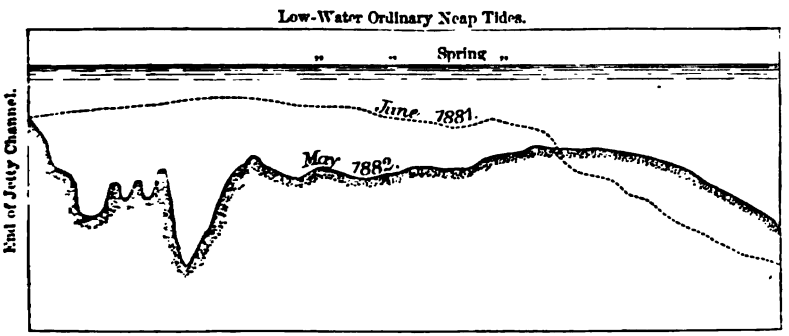
FIG. 2.



CALAIS HARBOUR.

Section in centre line of channel beyond jetties, showing results of dredging.

tities; secondly, the deep sea slopes were nearer the ends of the jetties; thirdly, the plant had been perfected by the experiments which had occupied time at Dunkirk. These advantages far more than compensated for the greater exposure at Calais.

[1] The contractor had therefore a balance of 3·52*d.* for insurance, deterioration, interest on plant, and profit. If 0·73*d.* was allotted for profit, there remained 2·79*d.* for the other items on 200,000 cubic yards in the year, equivalent to about 30 per cent. of the original value (£8,000) of the plant.

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The following Table furnished a comparison of the dredging operations at the two harbours for a period of nine months, ending the 31st of March, 1882. This comparison could be very easily made, as the sand-pump hopper-barge at Calais and one of those at Dunkirk were identical; they belonged to the same contractor, and were worked by equally experienced gangs.

Port.	Total amount dredged and removed in 9 months = 274 days by one dredger of 120 I.HP.	Number of regular working days.	Number of working hours.			Average product per hour of dredging.	Number of idle days.		Number of days during which the height of the swell was—		
			Dredging.	Conveyance, discharging, and stoppages at the site of the works.	Total.		Owing to bad weather.	For repairs.	0 to 1 foot.	1 foot to 2 feet.	Over 2 feet.
	Cubic yds.					Cub.yds.					
Dunkirk	79,205	151	1,410	498	1,908	56	80	6	116	119	49
Calais .	154,479	135	919	458	1,377	169	85	19	92	89	93

The influence of the greater purity of the sand at Calais was shown by the amount dredged in one hour being three times greater at Calais than at Dunkirk, with similar dredgers; the greater agitation, however, of the sea at Calais reduced this advantage, so that, in the end, the annual amount of work with the same dredger was only double at Calais what it was at Dunkirk. But as the length to be dredged at Calais beyond the jetties was only one-half that at Dunkirk, the same improvement might be effected at Calais with one-fourth the dredging plant, were it not probable that the greater mobility of the sand would necessitate a greater widening of the outer channel than at Dunkirk, both to the east and west, so as to provide receptacles beyond the regular channel for the deposits brought in by easterly and westerly storms.

When once the requisite depth was obtained at either harbour, some years' experience would still be needed to ascertain the average annual amount of deposit. For a long time a large part of the sand dredged would be due to the falling in of sand in the gradual formation of a gentle slope between the neighbouring banks and the bed of the channel, as well as to the aforesaid deposit. However, as the present work consisted in forming hollows near together, deeper than the required level, which filled up by the falling in of the adjacent sands, as well as by the deposits due to the winds, currents, and waves, a greater amount of silting up had to be contended with now than when the new

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state of equilibrium should have been attained; and it was therefore certain that the existing means of deepening would suffice for the future maintenance of the pass. The dredging of 196,000 cubic yards annually, costing under £6,000, would therefore suffice to maintain the pass at Calais. It seemed probable that the maintenance of the outer pass at Dunkirk would not cost more; it might even be less when the large accumulations of silty sand, in front and to the west of the harbour, were to a great extent removed by the great dredging operations for forming the channel. Messrs. Ploc and Guillai.

Though improvements effected by dredging would have to be maintained by dredging, they did not consider that sluicing could be dispensed with for maintaining the depth of these harbours. Although a small part of the sand and silt removed by the sluicing current might be deposited on the western beach, whence it would be brought back afterwards, owing to the course of the currents at Calais and at Dunkirk, it was certain that the greater portion would be carried out to sea and not return. The sluices, accordingly, ensured the scouring out of the inner channel and the portion of the outer channel near the ends of the jetties, an important gain accomplished at a small annual expense for working and maintenance.

To sum up, they considered that there were no absolute rules for these matters. The local conditions should be studied in each case, and if they admitted of powerful sluicing arrangements being cheaply constructed, this natural power should not be neglected. Very powerful sluices, suitably arranged, could maintain a depth of 13 feet below low water, between and for a short distance beyond the jetties, in sand of a favourable nature. Sluices alone would probably never lower the rest of the outer pass more than 6½ to 8¼ feet below the lowest tides. If this depth, added to the rise of tide, was insufficient, or if a great depth at low water was needed, for mail packets for instance, sand-pump hopper-dredgers, together with the most powerful sluices available, would certainly effect the desired result, at a cost which would vary according to the conditions of the sea and the purity of the sand; but which, from the experience at Dunkirk, Calais, and Boulogne, would not generally be excessive. The employment of dredgers for maintaining the jetty channel would necessitate a fairly large width, which it was not always possible or convenient to provide.

In every instance it was important to present as few obstacles as possible to the natural forces along the coast, not to raise solid jetties above the beach, and not to prolong the jetties, except when

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Messrs. Plocq and Guillain.

obliged by the progression of the foreshore. Solid jetties caused a progression of the dunes, and, consequently, of the whole beach; the extension of open jetties caused an advance of the low-water line, and thus increased the silting-up tendency of the beach.

The works of the Tyne and the Clyde were striking examples of remarkable practical successes attained by natural scour and dredging. They reasonably prompted the combination of artificial sluicing with dredging, as far as possible, where the tidal capacity of estuaries had been unfortunately compromised, and especially where these estuaries, converted into large rich tracts of land, could only flourish in rainy seasons by efficient drainage through the harbours.

Lastly, it should not be forgotten that the works at Boulogne were not strictly improvement works of the harbour, but consisted in the creation of a roadstead extending nearly 1¼ mile out to sea in front of the harbour, and that this project was in no way comparable with the improvement of the entrances to the harbours at Dunkirk and at Calais, and of the actual harbour of Boulogne. This artificial roadstead would give Boulogne what Nature had given to Dunkirk, and in a few years would render the deepening and maintenance of Boulogne harbour more easy.

Baron de Rochemont.

Baron QUINETTE DE ROCHEMONT was of opinion that the embankment of the lower Seine had considerably improved the navigation between Rouen and the sea; at the same time the channel below the embankments left much to be desired on account of its want of depth and of its shifting nature. The Rouen authorities had on several occasions demanded the extension of the embankments, but owing to the trouble they had occasioned in the regimen of the bay, and the fears entertained for the future of the Port of Havre, it had not been possible to go farther in that direction.

The ebb and flow caused very rapid currents both in the bay and in the river. The ascending currents passing over the shoals in the estuary got charged with sand, which was deposited at a point more or less near its origin; the descending currents acted to reconvey this material to its first position. But the ebb could not take back all the material brought in by the flood, consequently, little by little, silting occurred. Previous to the construction of the embankments an approximate equilibrium was established, and the depth of the annual deposit was relatively small. But this condition was altered by the embankments; the action of the ebb had been modified, it had become less than formerly, while the flood remained the same. The flowing current caused by the rise of the tide was virtually a factor of the tidal wave entering

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the channel. Its impetus was generated and developed in the open sea; and its action on the bed of the lower part of the outfall remained the same, whatever the reduction in capacity of the upper part, if the depth remained constant. Baron de Rochemont.

The section at the inlet had not varied; there the layers of water were of equal depth. The shoals inside the bay near the outfall were covered with water of less depth, at the time when the impulse of the tidal wave was still strong. Consequently they were easily eroded, and the flood tide carried silt as formerly. Towards the upper limit of the tide the speed of the current was progressively diminished to nil, when silting occurred with great ease. The water which formerly came up freely was now obstructed by the shoals, and could only act towards the east through the embanked channel; for the whole perimeter above the bay the water was without sensible velocity. Hence the deposit of matter in suspension lasted during the whole period of slack water at Havre, being not less than one hour and a half.

Formerly the ebb caused a tidal current over the shoals below the level of the water, which assumed a considerable slope between Quillebœuf and Havre. The average velocity increased and favoured the removal of part of the surface of the banks. This action made itself felt over the whole extent of the shoals; the fluid currents thus took up much of the deposit, which it reconveyed to the sea. This action continued very efficaciously till low water. At present the retreat of the water over the whole bay occurred without velocity. The point of departure, except for the embanked channel, had receded to the meridian of Hode. Not until much lower down was the velocity sufficiently accelerated to produce unsilting. The deposits situated above, no longer scraped off by the ebb, were gradually rising, and became uncovered at a much earlier period than formerly. True, the tide-level having been lowered in the Seine, a larger quantity of the water passed off by the channel, when the embankments were uncovered, but that produced no useful effect in carrying away silt.

The embankment of the Seine, by disturbing the former equilibrium, had therefore resulted in promoting the rapid shoaling of the bay. The growth of the deposit was progressively quicker as the alluvial matter found its depositing ground restricted by the daily diminution of the area of the bay, whose capacity was already decreased by one-half. This reduction of capacity of the bay had a further effect in modifying the regimen of the currents and tides. The secondary tide produced in the northern part of the mouth at the termination of the flood-tide, and when

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Baron de Rochemont.

the bay was full, had increased in a notable manner. It was normal to the jetties of the Port of Havre, and its maximum intensity coincided with the hour of high water. Its velocity had reached as much as 1·8 to 2·5 knots for tides of coefficient 100. This increase added to the difficulty of making the port. On the other hand, the time of high water was thirty-eight minutes later at springs, and seven to eight minutes later at neaps. At Honfleur the advance was nearly constant, twenty-six minutes. Mr. Vauthier was mistaken in maintaining that a new state of equilibrium had been established. On the contrary, the shoaling continued at a considerable rate. In January 1881 the zero curves (contour line of lowest known tide adopted by the Admiralty charts) passed through the meridian of 2° 12′ west of Paris, exactly where the 11-metre curve was situated in 1875. This deposit of 11 metres in six years deserved to be noticed, but Mr. Vauthier passed over it in silence. Little by little the shoaling was increasing at the outfall and approaching Havre. The entrance to the port, towards the south-west, was preceded by an almost level plateau, about a mile across, on which, at lowest neap tides, there was only a depth of 7·9 metres (26 feet). The least decrease in this depth would suffice to compromise the port.

Several mishaps having occurred to vessels ascending the Seine, while they were yet in the bay below the embankments, Mr. de Freycinet, when Minister of Public Works in 1879, appointed a commission to inquire into the improvements that appeared necessary in the regimen of the bay. That commission was composed of eminently competent persons: four Inspectors-General of the Ponts et Chaussées and Mines, two hydrographic engineers, a captain of the navy, and three delegates from the Chambers of Commerce of Havre, Rouen, and Honfleur. After an exhaustive study of the questions submitted, the commission concluded that it was necessary to abandon all prolongation of the embankments, and pay close attention to the movement of the shoals. It was not disputed that the lengthening of the banks would improve the entrance to the Seine, and that consequently it was for the interest of the river navigation. But at the same time the work could not be undertaken on account of the position of Havre at the mouth of the Seine, and of the disastrous consequences its execution would entail on the maritime interests of that port.

The improvement of the Seine outfall was therefore a particularly delicate matter. So far no solution had been found that would meet all the interests concerned. The hydrographers were engaged on a new survey of the bay to ascertain what had occurred

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since 1875, but the results of their observations were not yet made public. Mr. Vauthier had not brought forward any argument that was not already well known; it would therefore be perhaps prudent to await the report of the new survey to see if any new facts were brought to light which would result in the acquisition of a complete knowledge of the regimen of the bay. Baron de Rochemont.

Mr. G. Royers, engineer of the Port of Antwerp, remarked that the ports between Calais and Blankenberghe were, as the Author stated, kept up by jetties, nearly parallel, having an upper part of trestle work supported on a solid mound. The superstructure was to indicate the channel, to carry at the extremities signals, and to provide means for the warping of vessels. The solid part served to direct the sluicing current generally adopted, to prevent the ingress of sand, and to protect the piles of the trestle work from the force of the waves. It should be considered that this mode of construction was alone available on very flat sandy coasts. The line of the dunes or of high tide formed the limit of land and sea, and it was either just in front of or behind that line that the harbour must be made. If it were wished to establish a port beyond that limit it would be necessary, in order that it should be a port at all, *i.e.*, capable of affording shelter against storms, that space should be almost entirely closed in, capable of arresting the waves, and consequently the littoral currents. But if the free passage of these currents were interfered with there necessarily followed deposits, whose continuous action sooner or later effected the advance of the foreshore. The analogue of this was to be found in the convexity of a river curve when spurs were projected from the bank, and the result was all the more certain on a sea-coast, in that the tides on a shore worked two ways, and were of unlimited width. Experience showed that when it was desired to advance the coast, as for preserving embankments, or reclaiming land, no more effectual means could be adopted than of throwing out projections or obstructions. But if this were an excellent means of attaining a given end, it by no means followed that its efficiency was equal when the end was diametrically opposite. No doubt the advance of the shore might be made slower by the choice of a particular form for the obstruction, nevertheless it must be considered an axiom that the projection of a closed harbour from a sandy shore was, under all circumstances, very dangerous. Mr. Royers.

It was in view of this that the ports of the North Sea had been established on firm land, with open jetty approaches, which interfered as little as could be with the littoral currents, and it was hardly to be expected that good results could be achieved

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Mr. Royers. with solid jetties. Some engineers maintained that it would suffice to give solid jetties a curved form in order to prevent the advance of the shore. It was thought that such structures, carried out to a great depth of water, would prevent the accumulation of sand except in the exterior angles formed by the jetty and the coast, and that even this deposit would cease as soon as it had reached the exterior line of the jetties, where there could be no silting owing to the velocity of the currents. This opinion was not well founded, and although under such conditions the silting might take a long time to reach the end of the jetties, it could not be allowed that their construction would have no influence in disturbing the primitive equilibrium of the banks and channels. Another difficulty of the North Sea coast was the silty deposit formed by the water within spaces free from the agitation of the waves. These two circumstances had led, and would lead, to the establishment of ports within the coast-line connected with the sea by open jetties, affording a passage of limited extent opening into as many floating basins as possible. To maintain such channels no better system than sluicing had yet been discovered, and it successfully performed its functions. But to extend its effect as far as the bar, closing the entry to the ports, was a more difficult matter. So far the results had been mediocre. Perhaps it was that sluicing had not been applied on a sufficiently large scale. Considerable scour was produced close to the sluicing-basins when the water was let out, but the effect decreased rapidly near the sea, when the water escaped on all sides and did not retain sufficient force to affect the bar, or probably it was diverted into a direction different from that of the channel. The remedy was not obvious, nevertheless it might be that if means were found, as at Dunkirk, of guiding the sluicing-water and at the same time of providing an immense quantity, so as to be able to introduce into the channel more water in a given time than it could pass off, doubtless a notable effect might be produced on the bar. Such assisted natural action was far preferable to dredging, which, though it controlled the navigation to a certain extent, always had the disadvantage of not being applicable at certain times, especially in bad weather, when, as a rule, it was most wanted. It was obvious also that the filling-up by nature of dredging channels would follow very rapidly, and even supposing that dredging could be resumed immediately after a storm, some time elapsed in restoring the *status quo*. Sluicing might, on the other hand, be considered as one of the constants whose combined effect produced the configuration of the shore.

Experiments had been made at Ostend in the direction of

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guiding the sluicing-water by laying lines of big bottles or of saucissons, the former filled with gunpowder and the latter with dynamite, discharged a little before the water was let in, so as to blast a channel and prevent the spreading of the water over too large an area. So far these trials had not been successful, but they were interesting enough to deserve record. Mr. Royers.

It did not appear that there was any other mode of improving such ports as were in question, except by constructing breakwaters parallel to the sandbanks and consequently to the littoral currents. By this means the currents were not diverted, and the existing deep-water passes could be maintained, with the result that vessels could be sheltered from wind and wave at the same time that their anchorage was easily accessible. Ships would await the time of high water to enter the harbour basins, as was the practice in river ports, such as Liverpool, Hamburg, Bremerhafen, Rotterdam, Antwerp, &c. Such a system, assisted by copious sluicing, by dredging if necessary (securely protected by the breakwater), and other expedients such as blasting, jets of water under pressure, raking, and the like, would allow of a large development of the usefulness of harbours on the coast. It would even be possible from the moment the roadstead became safe to seek some means of raising vessels of heavy draught, as was done in floating docks, so as to pass them over the bar. It might be useful to search for some spot where the coast sloped rapidly, and where the depth was considerable, so as to apply some system allowing the vessels to reach the quays at all times of the tide.

The Port of Ymuiden was established on principles contrary to the foregoing, but Sir John Hawkshaw had told Messrs. Stœcklin and Laroche that he was only deterred from adopting the parallel jetty system by dread of the expense, and this opinion appeared to have been shared by Mr. Dircks, the Dutch engineer, who directed the works.[1] The converging jetties at Ymuiden had caused a certain advance of the foreshore, but their principal result had been a considerable silting-up inside. It had even been decided completely to abandon the effort to maintain the depth over the whole extent enclosed by the jetties, and it cost a great deal to keep up a channel only so wide as was necessary. It was not safe yet to pronounce judgment on the Ymuiden works, but it had certainly not been proved that they constituted any advance on the parallel jetty system with judicious sluicing, making allowance

[1] See note, p. 103, *post*.

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Mr. Royers. for the improvements which the latter was susceptible of, and of which the greatest was the establishment of detached roadsteads.

The foregoing considerations were equally applicable to the estuaries of rivers. As the Author stated, the outfalls of rivers through alluvial plains were principally maintained by the action of the tide. Such rivers should be capable of receiving the greatest possible volume of tidal water, and all artificial works tending to diminish it should be looked upon as dangerous. There was no doubt that the bed of a river might be improved by longitudinal embankments, but if those works in any way interfered with the volume of the waters scouring the estuary, their total effect would assuredly be prejudicial. To execute such works was akin to straightening and enlarging the corridor of one's house while at the same time narrowing the entrance, and they must assuredly bring about such results as the Author had indicated at the bottom of page 29, and would necessitate the prolongation of the jetty seaward. Prolongations of that sort were about the most dangerous things on the North Sea coasts, and without referring to the Hoek of Holland for confirmation, it might be acknowledged that their immediate effect would be to recede the lines of deep water further and further, and to create a bar more and more difficult to get over.

In these matters there was no absolute rule, but all those who attentively studied the conditions of rivers with outfalls into sandy estuaries of small depth of water would acknowledge that the least interference with the free scope of the tide would be eminently injurious. The principle to be followed in carrying out improvements in such cases was therefore to take great care that no river works should be allowed to lessen the impulse of the tidal wave; and if it were obligatory to encroach in particular localities, artificial excavations should be made in others to restore the equilibrium. Further, if such excavations tended to silt up they should be dredged. By this means works would only be carried out at places of acknowledged accessibility, while the other system led to the establishment of undertakings at inaccessible points, that was in the open sea, under immense difficulties, and whereof the results could never be ascertained with certainty.

Mr. Rymer-Jones. Mr. T. M. RYMER-JONES thought that the difficulties to be overcome or avoided in making a harbour at Madras arose from the strong sand-charged current which flowed periodically from north to south and south to north, according to the prevalence of the different monsoons. A breakwater, or system of breakwaters, if of a close form and commenced from the shore, would, in the first place, stop this natural current and cause an immediate deposit

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of the sand with which, close in-shore, it was heavily charged, thereby causing the rapid silting up of the shore ends of the breakwaters; secondly, the obstruction of the current for the whole length of the breakwaters seaward would create a race past their extremities which would cause a heavy scour, and also materially interfere with the steering of a vessel making the harbour. To avoid these difficulties (and aware that an open-piled pier of 1,000 feet in length, situated near the custom-house, had stood for several years without any accumulation of silt at all), he proposed to the Harbour Commission of 1868, at Madras, to utilise this pier with another and similar pier, to be built opposite the Madras lighthouse, situated 1,200 yards more to the south, so as to pass through the alongshore sand-bearing current without obstructing it, and afterwards to continue the breakwaters in stone sufficiently far seaward to give an anchorage of 265 acres, leaving two openings of 600 feet each, bearing N.E. and S.E. from the centre of the harbour, for ingress and egress of shipping with any wind. The advantage of passing rapidly through the almost continual surf on the Madras beach, before commencing the stonework, would be a great gain in itself. There were several other special points taken into consideration, which it was unnecessary to refer to. The vital principle in the design was the non-interference with the sand-bearing current and the avoidance of an expensive and useless struggle. The cost of the entire works, omitting the pier already completed, was estimated at £600,000. The alteration might be made even now if required. Mr. Rymer-Jones.

Mr. L. L. VAUTHIER generally agreed with the opinions on estuaries put forward by the Author. He was also in accord with him, that if it were advantageous to regulate an estuary very irregular in width, a too great reduction of the estuary channel would infallibly injure the outlet. But it should be borne in mind that it was impossible to consider an estuary apart from the river of which it formed the termination, or to leave out of account the oscillations of the sea into which it opened. Virtually, the essential factors which should govern the dimensions to be given to the mouth of a tidal river were the quantity of sea-water it received at every tide, and the volume of fresh water of which it was the conductor. It was incontestable that the larger the estuary the more sea-water it took and gave back. But it was not this water which contributed most advantageously to maintain the depths at its mouth. The water which was most efficacious in this respect was that, dammed back in the upper part of the river, that flowed away with the ebb, which, owing Mr. Vauthier.

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Mr. Vauthier. to the state of the tide, had but restricted channels to escape through. In a word, as regarded the dimensions connected with the tidal part of its bed, estuary included, every tidal river formed a particular case; a species of which the different elements required harmonising, and could not be considered separately.

The Author explained very clearly the benefits resulting from the embankments of the Seine; he also showed, with much precision (save in one particular, which Mr. Vauthier would indicate), the conditions of the bay below the extremities of the banks; and from these premises he drew the conclusion that, "The importance of tidal scour in maintaining the estuary of the Seine has already been clearly manifested by the changes resulting from the reduction of its tidal capacity; and if deep water did not exist in the sea in front of the mouth of the Seine, the maintenance of the outlet of the navigation channel might be liable, before long, to entail considerable trouble and expense."

It was this proposition that Mr. Vauthier questioned, basing his objections to it on some new facts, as well as upon those known to the Author. In order to be exact, he premised that in what followed, the term "estuary of the Seine," or "bay of the Seine," would apply only to the part below Tancarville Point, 16 miles in a straight line east of the meridian of Havre, and about 18½ miles by the river.[1]

Ever since their inception the works for the embankment of the Seine had aroused the apprehensions, real or feigned, of the Port of Havre; the objection being that the silt brought down by the embanked portion of the river (of which the mass was about 80 millions of cubic yards) would injure the entrance to the port and the small roadstead to the west. It was in consequence of these fears, and when land was being reclaimed on the north of the bay, under shelter of the banks, between Tancarville and Hode Points, 4 miles distant from the meridian of Havre, that the survey of 1875 was undertaken, under the direction of Mr. Estignard. This survey showed, as might have been expected, that during the forty preceding years important changes had occurred in the bay.

To the east of the meridian of Honfleur (distant 5·8 miles from that of Havre) much alluvial material had been deposited, both north and south, in the cove of St. Sauveur, situate between

[1] It resulted from this, that the training banks (which exist for 8 kilometres, 5 miles below Tancarville Point) project, on a line east and west, 4 miles into the estuary, and are not distant from the meridian of Havre more than 12 miles as the crow flies.

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Honfleur and Berville, and some alteration was noticed to the west of the meridian of Honfleur, continuing for from 1,200 to 1,500 metres beyond Havre, but on a much smaller scale. Thanks to the hydrographic chart of Beautemps-Beaupré, made in 1834, Mr. Estignard was able to trace these changes from the date named; but as to the eastern part of the estuary, owing to the absence of soundings in the above-mentioned chart, and in another made in 1853, he was only able to mark the changes since 1863, which had doubtless been very considerable in the previous period since 1834. Mr. Vauthier.

Mr. Vauthier would briefly indicate the result of Mr. Estignard's cubature of the two districts east and west of Honfleur, both as respects the amount of water permanently remaining below the zero[1] of the marine charts, and the mass of sand or silt above that level, and which he would designate emergent bottom (*fonds émergeants*).

In the region to the west of the meridian of Honfleur and north of 49° 26′ 30″, the permanent volume of water, which from 1834 to 1869 had diminished by 20 millions of cubic metres,[2] had from 1869 to 1875 increased by 32·6, or an effective addition of 12·6. In the same region the emergent bottom, which in 1869 had augmented by 25·3, had thence to 1865 diminished by 6·1, leaving the net increase 19·2. On the other hand, to the south of the same parallel, the relative figures were: for the water 28·8 and 22·8, indicating a final gain of 6. Of emergent bottom, from 1835–69 there was 3·5, while in 1875 this had diminished by 0·7; net increase, 2·8. Summing up these figures for the whole region, it would be seen that from 1834 to 1875 the permanent volume of water had increased by 18·6, while the emergent bottom had been augmented by 22. The result showed that for the whole period of forty-one years the increase of deposit was represented by 22–18·6, or 3,400,000 cubic metres. This was the result arrived at by Mr. Estignard, in Table VIII. of his report (p. 21).

Although this augmentation was small, it none the less contradicted that part of Mr. Vauthier's "Report on the Tidal Seine and its Estuary," which alleged that between the meridians 2° 5′ and 2° 15′ (west of Paris) there had occurred, between 1834 and 1875, an addition to the permanent volume of water of 22 millions of cubic metres. The discrepancy was, however, easily explained, as

[1] This unit approximates to the lowest tide ever observed at Havre.

[2] From what followed, the figures relating to volume of water would indicate millions of cubic metres, the 000,000's being omitted, 1 million cubic metres = 1,308,000 cubic yards.

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Mr. Vauthier.

was to be seen at p. 35 of the report in question. Mr. Estignard's cubatures related to the whole of what might have been called in 1834 the bottom, and extended to the firm shores of the bay, which had changed little, if anything, since that time. Now, since 1834, alluvial deposits had taken place between that point and the meridian of Honfleur. These deposits were only reached by exceptional tides, and did not, properly speaking, form part of the bottom at all. Well, their volume was at least 20 millions of cubic metres; if, therefore, Mr. Estignard's figures (for the north a final increase of 19·2, and for the whole region one of 3·4) were deducted, the amount of these deposits, the figures would be for the increase of the permanent volume of water 20 — 3·6, or 16,400,000 cubic metres, a difference from his own 20,000,000 too small to provoke controversy.

It was more important, however, to contest the Author's deduction from Mr. Estignard's data, "The early accumulation of deposit has doubled in the six years between 1869 and 1875." Although this statement did not refer specially to that part of the estuary comprised between the meridians of Honfleur and Havre, it would be convenient to treat it in the same way as should be done with the part to the east of Honfleur. Well, it resulted from the foregoing figures that, taking into account the simultaneous increase of permanent depth of water and emergent bottom, there was shown towards the end of 1869, as compared with 1834, to the north 45·3 increase of sand; to the south 25·3 increase of water, or a net increase of 20 of sand. In 1875 that had decreased to 3·4. Therefore the previous depositing action had been transferred to one of scouring. In this part, not only had the accumulation of deposit not doubled, but, on the contrary, it had decreased in the six years from 1869-75 at a much more rapid rate than it had increased in the thirty-five years from 1834 to 1869. He would revert to this while considering the other part of the estuary.

In the area to the east of the meridian of Honfleur, north of parallel 49° 26′ 30″, extending to the actual extremities of the training banks, the conditions were as follows, according to Mr. Estignard:—

The permanent volume of water increased 6·1 between 1863 and 1866, and diminished 2·3, thence to 1875, the net increase of water being 3·8. The increase of shore, which previously had been — 4·1, had in the second period been + 85, or a net mean of 81·3. If were added that, from the extremity of the banks at La Roque Point (where they ended in 1863) there was between that date

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and 1875 an increase of water of 3·8, and of deposit of 33·3, it would show to the north an increase of water of 3·8 + 3·8 = 7·6, and of deposit of 85·1 + 33·3 = 118·4, finally a net increase of deposit of 118·4 − 7·6 = 110·8. Mr. Vauthier.

In the southern part, the volume of water had diminished from 1863 to 1866 by 0·4, and from 1866 to 1875 had increased by 4·2, or a net increase of 3·8. In the same periods the deposits had increased respectively 0·5 and 53, or 53·5 in all, indicating a net increase of deposit of 53·5 − 3·8 = 49·7. Adding together these figures, indicating the changes north and south of the district east of Honfleur, there resulted 110·8 + 49·7 = 160·5; and allowing for the 20 millions of cubic metres deposited on the north side between Hode Point and the Honfleur meridian, the amount of deposit from 1863 to 1875 would be, to the north 110·8 + 20 = 130·8, and to the south 49·7, together representing 180·5 millions of cubic metres.

Mr. Vauthier found nothing to dispute in these results. He admitted also that the volume of water entering the bay above the Point Hode meridian, 3 kilometres west of that of Honfleur, might have diminished, as Mr. Estignard had calculated, to the extent of 138 at springs and 61 at neaps, or a mean of 99·5, say 100 million metres. But the figures quoted above indicated that from 1863 to 1866 the deposits below the actual extremities of the training banks were nothing at all; and that consequently it was between 1866 and 1875 that the existing alluvial deposits had taken place, but in the latter period of nine years there was nothing to show that the rate of deposit was greater at the end than at the beginning. He was even led to believe, in the absence of authentic data, that it was immediately after the completion of the training banks in 1867 that the deposits became considerable. Their rate of growth would be less as they increased in depth, and so decreased the layer of sand-bearing water by which they were formed. Some further indications tended to confirm this view.

After giving these facts, which a simple inspection of the bay might have established, it was not surprising that Mr. Estignard should find that the opinions of Mr. Bouniceau were inexact, and that the source of the considerable deposits he had shown must be sought elsewhere than in the fresh water detritus brought down by the Seine, or the natural erosion of seashore. This source was doubtless the bed of the western part of the bay and that of the open sea. If the hydrographic surveys of the bay of the Seine were not enough extended, so as to include the whole of

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Mr. Vauthier.

the beds supposed to be laid under contribution, it would be, however, impossible to search elsewhere for the real source of these deposits. But Mr. Estignard might fairly be asked if he had argued soundly, when, after accepting these two facts—the reduction of the bay already brought about, and the limitless abundance of the material suitable for being there deposited—he had considered the ultimate reduction of the capacity of the bay as an infallible event, bound to result sooner or later.

The unstable nature of the sand or silt which formed the beds of open seas, which the least agitation stirred up, had not been considered by Mr. Bouniceau; perhaps, on his part, Mr. Estignard had omitted the conditions under which alone this shifting material might subside in the river bed. These conditions were almost absolute quiescence of the liquid that held them in suspension, and a continuance of this quiescence in proportion to the fineness of the particles suspended.[1]

He would give a few figures showing how far these conditions should be taken into account. Mr. Estignard admitted that an average tide inclosed in the bay of the Seine would leave behind it a deposit of about 3 millimetres (0·118 inch). That engineer did not insist on the figure given, but from numerous observations and comparisons Mr. Vauthier was led to believe it was very near the truth. Now, the bay of the Seine, from the meridian of Havre east had a surface at spring tides of 160 millions of square metres, and at neaps of 115 millions, or an average of 137,500,000 square metres. It followed that the amount of solid material in an average tide was 412,500 cubic metres, which, for the 707 tides of the year, gave a volume of 291,637,500, or say, in round numbers, 300 millions of cubic metres. That granted, in considering only the period of nine years, between 1866 and 1875, the tides had floated over the bay 2,700 millions of cubic metres of solid material, of which had been deposited only 180 millions, or a fifteenth part. What had become of the rest? Brought in by the flood, it had been taken away by the ebb, and, notwithstanding

[1] Sufficiently exact observations did not exist of the time necessary for the deposit in still water of particles of various sizes held in suspension. All knew that, other things being equal, the larger particles subsided first, and his own calculation had shown that in a tranquil fluid the deposit of matter of a specific gravity of about 2·5 was very nearly proportional in time, and that the fall per second was in direct proportion to the thickness of the falling body. Water in which fine sand would be quickly deposited might remain turbid for days under the influence of impalpable matters, which the least agitation would cause to rise like clouds.

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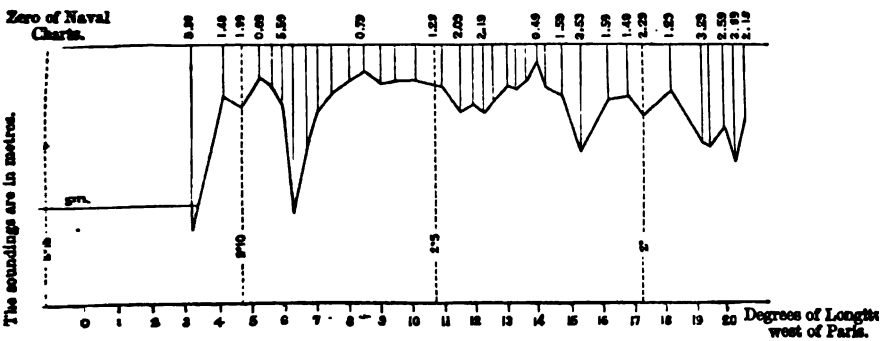
the indefinite volume of material suitable for deposit, it only sufficed to prevent augmentation of the deposits, and for the establishment of an equilibrium, that currents equally powerful should sweep over the whole of what still formed the surface of the bay. Did this equilibrium really result under the conditions of the chart of 1875? Mr. Vauthier had thought so at the time he wrote his report on the tidal Seine and its estuary. A new hydrographic survey made in 1880, and of which the results were not yet fully known, seemed to indicate that he had been deceived. Mr. Vauthie

The growths of the deposits in the bottom of the bay had not been relatively considerable, and the channel between the ends of the training banks and the sea had been rather improved than deteriorated. Fig. 3 gave a longitudinal section of it, which, com-

FIG. 3.



LONGITUDINAL SECTION OF THE ESTUARY OF THE SEINE FROM THE HYDROGRAPHIC SURVEY OF 1880.

pared with the section of 1875 (Annex No. 27 to his report) (Plate 3, Fig. 2) would evidence the fact, at least so far as concerned the part shown. He would add that the approaches to Havre had also improved. But the salient fact shown by the report in question was, that there should have been deposited in the lower parts of what he had called the trench (*fosse*) of the deep water between the Amfard and Ratier shoals, materials estimated at 32 millions of cubic metres. The 5-metre and 10-metre contour lines below the zero of the naval charts, instead of advancing towards the east, as from 1834, had retrograded. Could the deposit in question be regarded as a consequence of those alternate movements inherent in all matters appertaining to the sea? Or, on the contrary, did it show a failure of the erosive power of the ebb? Under correction of

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Mr. Vauthier. what might be shown from the survey of 1880, Mr. Vauthier believed in the latter hypothesis; and Mr. Vernon-Harcourt, who had with such justice seen at a glance that the critical part of the bay of the Seine was that which lay between the meridians of Honfleur and of Havre, would certainly support his opinion.

On examining attentively the chart of the bay of the Seine of 1875, it was unquestionable that the deposits north and south had happily regulated the contours. Alone, the projection of the deposits in the south under the 2° meridian (west of Paris) was extremely unfavourable. It was this prominence, which violently diverted the channel in a northerly direction immediately after its issue from the embankments, that was one of the principal causes of its subsequent sinuosities. But this fault was, or should be, easily cured. On the other hand, with respect to the part below Tancarville Point, the Author shared his own opinion that the banks were not only too close, but that they were badly planned. In short, doubtless the necessity of considering at the same time the ports of Honfleur and of Havre, had rendered it necessary to give to the outlet of the bay a width greater than would otherwise have been advisable. Nevertheless, the governing defect was the insufficiency of the waters of the ebb.

Mr. Vauthier had in his report, several times quoted, suggested means of augmenting the volume of the ebb in proportion to the fault to be remedied and the effects desiderated. It had been pointed out that, with an average tide, there entered the bay at least 100 millions of cubic metres of water. On the other hand, he had shown that the volume ascending the Seine, to about 20 kilometres above Rouen, could be augmented by 30 million of cubic metres. These two amounts, differing in themselves, had an enormous difference in their mode of action. The first advanced and retired at a time when, towards the mouth, the bottom was still covered with a considerable depth of water. The second, coming from a great distance to the ascent, would abrade the bottom when the tide, nearly at ebb at the mouth, had greatly reduced the area of its water way, and would concentrate its useful effect on the navigable channel.

The profiles of 1875 (Annex 2, 3 of the report) between the meridians 2° 10′ and 2° 8′ (west of Paris) included the site of a shifting bar, which in spite of the variations in height and situation caused an almost permanent obstacle. If on these profiles were traced the average high tides of 7 metres above the zero of the charts, and the average low tides of 1·7 metre above the same datum, it then would be easily shown that the 100 millions of

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cubic metres rejected could only produce a much less effect on the sides of the great section, than the 30 millions of cubic metres produced in those of the smaller one. Mr. Vauthier.

Mr. Vauthier was convinced, notwithstanding the difficulties of the problem—and without disputing the advantages which might accrue from narrowing somewhat the mouth of the estuary of the Seine—that the new forces of which it was hoped to develop the action would afford an effectual solution. He would be even more confident if engineers like Mr. Vernon-Harcourt should arrive at a similar opinion.

Mr. E. WIDMER considered that the Author had clearly shown the critical situation at present existing in the Seine estuary. Consequent upon the diminution of the filling-area, the silting continued, and at several points the depths tended to decrease to a notable extent. This fact, already indicated by Mr. Estignard, had been confirmed by a hydrographic survey made in 1880 under the direction of Mr. Germain, who had recently published the results. There existed at the mouth of the Seine, nearly in the meridian of Havre, two permanent shoals, known as the Amfard and the Ratier banks. In conjunction with the north and south shores these banks formed three mouths of nearly equal size. The waters of the Seine at low tide were concentrated sometimes in one, sometimes in another of these mouths, and constituted the channel which had to be followed by vessels going up to Rouen. From 1875 to 1880 this channel maintained itself in the middle route, between Amfard and the Ratier, in spite of the frequent variations in that part of the river between the meridian of Berville and Havre. Nevertheless, Mr. Germain's soundings showed that at the outer end of this channel the greatest depth, which in 1875 reached to 19 metres (62 feet) below low water of the lowest tides, only gave 11 metres in 1880. By comparing his soundings with Mr. Estignard's survey, Mr. Germain had been able to calculate very closely the cube of the deposits formed in the five years as follows: "We may estimate at more than 30 millions of cube metres (39,240,000 cubic yards) the material deposited from 1875 to 1880, between a meridian passing through the ends of the Seine jetties and one passing 5 kilometres towards the crest distant from the mouth of the Port of Havre (which appears to form the western limit of the changes in the bottom of the estuary). It is to be remarked that nearly the whole of these deposits have occurred in a length of 6 kilometres of the channel between Amfard and the Ratier." Mr. Widmer.

The difficulty of remedying this state of affairs was well shown

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Mr. Widmer. by Mr. Vernon-Harcourt. The only means of assuring in the Seine a channel of suitable depth would be to prolong the jetties seaward. But this would at once generate accretions, which would sooner or later be fatal to the ports of Havre and of Honfleur. Mr. Vauthier's plan would doubtless obviate this latter disadvantage, since his proposed banks would be almost entirely founded upon shoals, which were at present above high water of neap tides. But under these conditions such constructions would be absolutely without influence on the shifting channel, seeing that they would be established at points beyond the range of its variation.

The hydrographic survey of 1880 showed that up to that time the accretions to the shore in the neighbourhood of Havre had not caused serious inconvenience. But the enormous shoaling between Amfard and the Ratier, at a distance of less than 2 kilometres from the deepest channel leading to the port, could not fail to cause the engineers the liveliest concern. They were occupied at present in plans for changing the entrance to the port. The existing jetties, which pointed south-west, would be replaced by others established towards the north-west, in a direction where the soundings within 500 or 600 metres of the shore gave a depth of 3·5 metres (11½ feet) below the lowest tide. The channel to the port would thus be notably distant from the site of the shoals encountered by Mr. Germain. When this important work was completed, perhaps it would be time to consider the expediency of prolonging the Seine jetties. It would, however, in any case, be indispensable to make a fresh survey, and if that decided the undertaking of the prolongation, then to proceed by piecemeal, so as to judge of the effect.

At present, the situation of Honfleur was not so critical as might appear at the first blush. For many years nature had maintained near the southern coast of the estuary a false channel, which was fed at falling tide by the drainage from the banks towards the Fosse de Villerville. This channel, which ascended to a point more or less up the eastern side, was at present stationed opposite Honfleur. Thanks to this, it was easy to maintain by means of the great sluicing basin, 50 hectares (123 acres) in extent (finished in 1881), depths greater than were necessitated by the sill of the lowest lock. The depth on this sill did not exceed 7 metres (23 feet) at high water of spring tides, nor 5 metres at high water neaps.

Concerning the navigation to Rouen, as it was hopeless at present to attempt to fix the channel, attention was concentrated on its efficient buoyage. Moreover, provision had been made for the time, at present perhaps far distant, when the silting with

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which it was useless to contend would close the Seine to large vessels. The canal from Havre to Tancarville, being made at present through the alluvial deposits of the northern side of the estuary, would at first be constructed entirely in the interest of the river navigation, and have a depth of 3·5 metres. It had been decided that the works of art to be established at each end of the canal should from the first be of dimensions sufficient for passing vessels of a tonnage equal to those frequenting the Port of Rouen, the bed being made sufficiently wide to allow of subsequent deepening by simple dredging. The important city of Rouen would therefore be able to maintain its port by means of the Tancarville canal. Mr. Widmer.

Mr. J. Evelyn Williams remarked with reference to harbours on sandy coasts, that he thought it would be found when a solid groyne or pier was constructed so that it formed an abrupt projection to the contour of the coast, the advance of the low-water line seaward invariably followed. This was no doubt caused by the solid structure intercepting the littoral currents which carried sand in suspension, and it was only by further works or dredging that the gradual accumulation of sand would be arrested and the equilibrium of the harbour be established. The several piers in Whitehaven Harbour afforded an interesting illustration of the steps taken to acquire a sheltered deep-water accommodation. It was not until the completion of the seaward extension of the west and north piers that the desiderated equilibrium was attained. By the lengthening of these piers the embayed contour of the coast-line as affecting the harbour was destroyed, and the prejudicial effects of the littoral currents were at the same time reduced to a minimum. Mr. Williams.

With reference to estuaries, the training of the fen rivers falling into the Wash had no doubt led to beneficial results so far as the works extended, but the effective improvement was almost rendered nil owing to the training of the outfalls not being continued to deep water. At the termination of the training or guide walls the concentration of scour was diffused, and the remaining portion of the channel became tortuous and shallow. It was only by forming a direct and defined outfall to deep water, as the new cut for the Witham then in progress, or by continuing the concentration of scour to the estuary by directing and training the existing outfall channels, that the improvement of rivers could be permanently effected.

Mr. Vernon-Harcourt, in reply to the correspondence, observed that Mr. Aitken proposed that dredging alone, without guiding- Mr. Vernon-Harcourt.

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Mr. Vernon-Harcourt.

piers, should be employed for forming the entrance channels to ports. He, however, considered that jetties, carried up solid to the natural level of the beach, were advantageous if merely extended to low-water mark, which was the farthest limit the jetties of the North Sea ports could attain, in spite of prolongations. It must also be remembered, in justice to the designers of those and other harbours, that only within the last few years had it been found practicable to accomplish dredging in the open sea.

He was glad that Mr. Caland was in a position to state that the cut through Hoek of Holland was being enlarged, as its narrowness appeared to him one of the principal causes of the inadequate depth at the mouth. He had always thought that full justice had not been done to the design by the method of forming the cut, and by the work having been left incomplete; and, though his Paper had been written before the work referred to by Mr. Caland, he was not aware of any change of views in the interval. He could not agree with Mr. Cay that it would have been advantageous to put locks across the new outlet of the Maas, as he believed that, though the range of tide was small, the constant tidal oscillation up and down the channel prevented the deposit of sand and silt, whilst the river water gradually conveyed the suspended matter out to sea. He thought that a breakwater parallel to the coast, suggested by Mr. Cay for Dunkirk, and by Lieutenant Petit for Ostend, might be useful in protecting the entrance to the harbours, thus facilitating dredging operations and the entrance and exit of vessels, which was now to some extent effected by the sandbanks in front. The breakwater, however, would require to be placed near the coast, or made very long, to afford an ample protection; and he did not see how such a structure, if placed in a straight line end on to the current, could have any effect on their course. Probably, however, some concentration of the inshore currents might be gained by curving the breakwater towards the shore opposite the entrance.

It had been remarked by Commander Cialdi, that the Paper left much to be desired in the way of suggestion for the improvement of harbours on sandy coasts, but he did not venture on any suggestions, though so very competent to do so, except that jetty harbours were the only available method, whilst admitting that hitherto they had not been satisfactorily improved. Mr. Vernon-Harcourt believed that the discussion had fully made up for any deficiencies in his Paper; but he would add a few brief remarks on the general question. Four principal methods had been adopted, or proposed, for forming harbours on sandy coasts: (1) the jetty system;

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(2) closed harbour with converging solid piers; (3) an outlying detached breakwater; (4) one or more sheltering breakwaters connected with the shore by one or two open viaducts. Advocates of each one of these systems had joined in the discussion, and each system might prove the best in different localities. Mr. Vernon-Harcourt.

The jetty system had its advantages on a fairly sheltered coast; it was economical and simple in construction, and did not interfere materially with the littoral currents and wave action when not prolonged beyond low-water mark; the inner channel and the nearer portion of the outer channel were readily kept clear by sluicing; the farther portion of the outer channel could only be maintained by dredging. The method of converging, instead of parallel, jetties, suggested in the Paper, had the advantages of increasing the scour at the entrance, of reducing the swell entering the harbour, of affording scope for dredging inside, and of projecting less abruptly from the land.

Solid piers extending out from the shore, at some distance apart and then converging at their extremities, possessed the advantages of promoting tidal scour at the entrance, of serving for refuge on exposed coasts, of protecting dredging operations inside, and of being capable of being carried into deep water. Their maintenance depended on the depth and scour at the entrance, and on the conditions affecting the progression of the shore.

An outlying breakwater parallel to the coast line would afford protection without interfering with the littoral currents; but it would require to be near the shore, or facing a bay, or of considerable length, to protect any portion of the coast from every quarter. This kind of structure, being unconnected with the shore, would merely serve as a protection to inner works.

Solid breakwaters placed in deep water and connected with the shore by open viaducts, so as not to arrest the littoral drift, appeared well adapted for sandy coasts; but the connecting viaduct, and the extent of the breakwaters situated in deep water, needed to shelter any large area, rendered this an expensive type.

It was evident that the dredgers used at Ostend, referred to by Mr. Duckham, were not large enough, though they had accomplished a fair amount of work; if the same sized dredgers were employed there as at Dunkirk and at Calais, the deepening of the outer channel would be doubtless satisfactory.

A bold scheme for the formation of a harbour on a large scale, at Ostend, had been proposed by Mr. Griffith, similar in fact to the plan adopted at Boulogne, but unfortunately in a far less favourable position both as regarded the site and the supply of materials.

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Mr. Vernon-Harcourt.

The situation was also much more exposed than the works on the Liffey in Dublin Bay, to which Mr. Griffith had referred. No doubt a closed harbour extending out beyond the Stroom Bank would not be injured by any progression of the foreshore for a long time, especially as the entrance would stretch far beyond the regular line of coast, and it would resemble Ymuiden or Madras on a large scale. It was really a question of policy and cost. Did the prospects of the Port of Ostend, or the national interests of Belgium, justify the very large outlay that would be necessary to form a large closed harbour at Ostend? From a merely commercial point of view, it must be acknowledged that Antwerp was by far the most important and growing port of Belgium, and that Ostend had little prospect of a similar advance, though an improvement of its approach might do much. It would require a more careful study of the very peculiar local conditions of Ostend than he had had an opportunity of making, before he could say what, in his opinion, would be the best means of improvement of that particular port; but he was inclined to think that dredging should first be tried on a more extended scale, with an enlargement and concentration of the sluicing basins, and that a detached breakwater might be designed for the protection of the entrance. Dunkirk, Nieuport, and Ostend were peculiarly unsuited for the formation of closed harbours. Mr. Keller had mentioned his proposal of converting a portion of a closed harbour into a sluicing basin by shutting it off at high water. That plan had been adopted by Smeaton at Ramsgate harbour, though not near the entrance as Mr. Keller suggested. At the present day, dredging would probably prove a more economical way of removing a bar. Curiously enough, Lieutenant Petit, who was intimately acquainted with Ostend harbour, had expressed his preference for a funnel-shaped mouth to jetty harbours, whereas Mr. Rawlinson had specially objected to this shape at Ostend as intensifying the swell entering the harbour. Mr. Vernon-Harcourt agreed with Mr. Rawlinson's view; but probably the protection of the Stroom bank had prevented much swell from entering the harbour, and the funnel shape was advantageous for the entrance and exit of vessels, though unfavourable for the efficiency of the sluicing current at the mouth.

He was glad that Mr. Pettit, the engineer at Bayonne, had added some very interesting particulars about the Adour jetties. It was unfortunate that the method of rendering the jetties close or open, by lowering or raising panels, had not been found workable, as the results of the experiment would have been of value. Messrs. Plocq and Guillain had furnished most valuable details relative to

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Boulogne, Calais, and Dunkirk, and had shown very clearly how the depth of water and the purity of the sand affected the cost and the results of dredging. He fully agreed with most of their remarks, and particularly in the distinctions they drew between the different sites. He thought, however, that the new works at Boulogne, though differing from the methods of improvement at Calais and Dunkirk, would not merely form the roadstead to the port, but, by providing a deep water entrance and preventing the inroad of sand, would be the real harbour of Boulogne, thus changed from a jetty harbour to a closed harbour, and the old jetty harbour would become merely the channel of approach to the docks. Messrs. Quinette de Rochemont, Vauthier, and Widmer, had confined their remarks to the changes in the Seine estuary with which they were well acquainted. He felt unable to reply properly to their very interesting observations, as he did not possess any information relative to the survey of 1880, not yet published, to which they referred. It appeared, however, that a considerable amount of silting-up had taken place between 1875 and 1880, and that therefore a state of equilibrium had not yet been reached. It might turn out that the maximum of deposit had been attained in 1875, and that the rate of deposit was now diminishing. Till, however, the silting up should be proved to have stopped, the shifting channel below the embankment, and the approaches to Havre, could not be considered safe from injury. Even then the prolongation of the embankments would be desirable, in the interests of the river navigation, for regulating and deepening the outlet channel; but this would occasion fresh changes in the estuary, dangerous to the Port of Havre unless its entrance could be altered, which Mr. Widmer said was under consideration. Mr. Royers was an advocate of the jetty system aided by sluicing and protected by a detached breakwater. Mr. Vernon-Harcourt agreed generally with his remarks on these points, and on the maintenance of estuaries, whilst thinking that he unduly depreciated the value of dredging. He had, however, read with some surprise Mr. Royers' remarks on Ymuiden harbour, as the preference attributed to Sir John Hawkshaw for the parallel-jetty system, over the closed harbour actually constructed, was the exact opposite to the views expressed by that gentleman about the improvement of Calais in the discussion on the Paper.[1] He had accordingly asked Sir John Hawkshaw

Mr. Vernon-Harcourt.

[1] Mr. Royers has since informed the Secretary that his authority for the statement was a report by Messrs. Stoecklin and Laroche, "Des Ports maritimes considérés au point de vue des conditions de leur établissement, &c.," p. 64 par 4. Boulogne, Simonnaire, 1879.

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Mr. Vernon-Harcourt.

whether he had ever entertained such an opinion with reference to Ymuiden harbour, and was told that he had not. Mr. Royers must therefore have been misinformed in the matter. Moreover, the supposed reason given for the adoption of the converging breakwaters at Ymuiden, namely the greater cost of the parallel jetty system, appeared untenable, as, whatever might be the advantages of converging piers over parallel jetties in certain cases, economy in construction was not one of them. Mr. Rymer-Jones appeared to have proposed a plan for Madras harbour somewhat the same as suggested by Sir Andrew Clarke, and similar in principle to the harbours as designed for Port Elizabeth and partially carried out at Rosslare. This system of open viaducts from the shore leading to sheltering breakwaters gave a good prospect of maintenance; but in the case of Madras it would have necessitated the breakwaters being extended into a considerable depth of water. The cost, however, of this method was the only objection to which it seemed open. In conclusion he desired to express his thanks to the foreign correspondents who, by furnishing details and observations on subjects which had come under their personal experience, had so greatly added to the value of the discussion.

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2 May, 1882.

EDWARD WOODS, Vice-President,
in the Chair.

The following Associate Members have been transferred by the Council to the class of

Members.

WILLIAM HARVEY.
JOHN HOPKINSON, M.A., D.Sc.
SYDNEY STENT.

The following Candidates have been admitted by the Council as

Students.

WILLIAM MARROW BECKETT.
ROBERT HIGHET.
HENRY SYDNEY JONES.
HORACE HASSALL RODEN.
ALBERT CASSON SMITH.
RALPH FREDERICK SMITH.
JOHN TRUMP.

The following Candidates have been balloted for and duly elected as:

Members.

ROBERT ASKWITH.
ARTHUR BRANDER GATHERER.
JOHN CARAPIET VEETANNES.

Associate Members.

ALAN CHARLES BAGOT.
CHARLES WILLIAM BEST, Stud. Inst. C.E.
FREDERICK SEPTIMUS BRUNTON.
FRANCIS CRAWFORD CAFFIN, Stud. Inst. C.E.
EDWARD CASE.
JOHN HAWDSLEY DALBY.
JOHN PATON DAVIDSON.
JAMES DAVID DAVIES.
ALFRED THOMAS DAVIS, Stud. Inst. C.E.
JAMES BARRETT FINNEY.
ROBERT GOULD.
FREDERICK CHARLES PEMBROKE JONES.
THOMAS NESHAM KIRKHAM, Jun.
CHARLES GRIFFIN LAWSON.
GEORGE AUGUSTUS HAMILTON FITZWARRINE LLOYD, Stud. Inst. C.E.
RICHARD ROBERT MENNEER.
RICHARD MARION PARKINSON, Stud. Inst. C.E.
EDWARD STUART PRESTON, M.A.
WILLIAM FLETCHER ROBINSON.
DAVID CARNEJY SIMPSON.
ERNEST SPON.

Associate.

WALTER JOHN CHARLES CUTBILL.

The Discussion upon the Paper on "Harbours and Estuaries on Sandy Coasts," by Mr. L. F. Vernon-Harcourt, occupied the evening.

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May 9, 1882.

SIR F. J. BRAMWELL, F.R.S., Vice-President, in the Chair.

(*Paper No. 1870.*)

"Coal-Washing."

By THOMAS FLETCHER HARVEY, Assoc. M. Inst. C.E.

THE object of this Paper is to describe the operations and the machinery connected with the separation of coal from the schistose and other impurities associated with it, having special reference to the manner in which this is effected in South Wales.

The importance of separating coal from the incombustible impurities which are always found with it when brought out from the coal mine, may perhaps be strikingly shown if a brief consideration be given to the effects resulting from the use of impure coal, both in metallurgical operations and in generating steam in boilers; and as these two processes consume a large portion of the whole output of coal in the kingdom, it is obvious that any loss entailed by neglecting to remove these impurities must be a loss of great magnitude.

Therefore it may be well, before entering into a description of the machinery and operations of coal-washing, to estimate approximately the loss due to a given percentage of incombustible impurities in the fuel used for smelting iron in a blast furnace as typical of metallurgical processes, and also to consider the same question with reference to the generation of steam.

The incombustible impurities present in coal consist for the most part of silicate of alumina together with some oxide of iron. In blast furnaces, the oxide of iron is reduced, and may therefore be deducted from the loss account of fuel consumed in such furnaces; but when present in fuel used under steam boilers it forms into clinkers on the bars of the furnace, resulting in great loss.

Silicate of alumina enters into the composition of coal ashes, often to the extent of about 90 per cent. of the whole, the proportion of silica to alumina varying between $\frac{3}{4}$ and 2, the higher proportion

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generally existing in coal with the higher percentage of ash. This silicate is almost infusible, even at the temperature of blast furnaces, and in order to make it sufficiently fusible for the good working of the furnace it requires an addition of lime.

In blast furnaces working on Bessemer iron the slags are generally of about the following composition:—Lime 47, alumina 15, silica 38. The proportion between the alumina and lime is as about 1 to 3; but if lime be added in the same proportion to the alumina of the ashes of the fuel, the proportion of the bases to the silica in the fuel will be much greater than in the Bessemer slag. However, to prevent an exaggerated estimate of loss, in the following calculation lime will be added only in sufficient quantity to make the ashes of the fuel as basic as the remainder of the slag produced in the furnace.

It will be assumed that 22 cwt. of coke, containing 92 per cent. of carbon, 5 per cent. of ash, and 3 per cent. of moisture, will produce 1 ton of Bessemer iron. With these data, the following calculation will show the amount of coke required when the carbon is 82 per cent., ash 15 per cent., and moisture 3 per cent., the principal elements of the ash being, silica 49 per cent., alumina 25 per cent., and lime, &c., 8 per cent.:—22 cwt. of coke, with 92 per cent. of carbon, give 20·24 cwt. of carbon per ton of iron. Again, 20·24 cwt. of carbon represent 24·7 cwt. of coke when there is 82 per cent. of carbon; that is to say, coke with 15 per cent. of ash. The 10 per cent. of extra ash in the dirtier coke = 2·5 cwt., consisting of 1·23 cwt. silica, 0·82 cwt. bases, 0·45 cwt. oxide of iron. The bases take up 0·5 cwt. of silica, leaving 0·73 cwt. to be fluxed by adding lime to the extent of 1·2 cwt., which is equal to 2·2 cwt. of limestone. The total slag due to the extra 10 per cent. of ash in the coke will therefore be 3·7 cwt., consisting of 2·5 cwt. of ashes + 1·2 cwt. of lime.

	Cwt.-Units.
The fusion of 3·7 cwt. of slag requires, according to Bell, 3·7 × 550	= 2,035
To expel the carbonic acid from 2·2 cwt. of limestone requires 2·2 × 370	= 814
To decompose 0·264 cwt. of carbonic acid of the limestone requires 0·264 × 3,200	= 845
Total cwt. heat-units	3,694

Taking 4,400 as the number of units developed by 1 cwt. of carbon in the blast furnace, the above will represent $\frac{3,694}{4,400} = 0·84$ cwt. of carbon. Therefore, instead of 20·24 cwt., the carbon

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with the inferior coke must be 20·24 + 0·84 = 21·08 cwt. Consequently the coke required with 15 per cent. of ash will be 82 : 100 : : 21·08 : 25·7 cwt., being for every ton of iron produced 3·7 cwt. more than in the case of coke with 5 per cent. of ash; or about 17 per cent. extra coke. To this loss should be added the cost of 2¼ cwt. of limestone, which in itself would almost cover the cost of washing the coal.

But there are other losses through the use of impure fuel, which, if not so great as those already mentioned, are nevertheless formidable. In the first place, there is an increased cost of transit, bearing a direct proportion to the percentage of impurities carried, requiring additional rolling stock, and secondly, increased cost in the manufacture of coke.

Assuming, for illustration, that the coke produced contains 10 per cent. of ash which can be removed by washing, it has been necessary to provide sufficient coking plant to allow the tenth part of the whole to be unproductive so far as coke is concerned. Thus if ninety coke ovens will produce the desired quantity with washed coal, the additional ten ovens required in the assumed case, at a cost of £100 per oven, would represent a substantial outlay, which, to say the least, might have been more profitably spent in coal-washing apparatus. Moreover, all labour cost in the coking department has been increased, and the loading, conveying, depositing, and filling into the blast furnace have represented in each instance the additional cost.

With regard to the generation of steam in boilers, the principal source of loss due to the ash in the fuel is that arising from the difficulty of effecting economical combustion, owing to the ash forming a clinker on the bars of the grate, which allows large streams of air to pass through the furnace, without having been properly mingled with the fuel on the bars, such air carrying away the heat and reducing the temperature of the furnace. The following quotation from "Percy's Metallurgy" well describes the action of the ash in boiler furnaces:—

"When the ashes sinter together or melt, they form a more or less vitrified mass termed clinker, which may accumulate upon the bars so as greatly to impede the passage of air between them, and, as a consequence, lower the temperature of the furnace. Moreover, when the bars are covered with a firmly-adherent bed of clinker, and are no longer cooled by a continuous current of cold air, they may soon become heated and destroyed by oxidation."[1]

[1] "Metallurgy: Fuel." By John Percy, M.D., 1875, p. 280.

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The amount of loss caused by the passage of air through the furnace, and which does not support combustion, cannot be even approximately determined, but that it is considerable is evident from the slow combustion and low evaporative duty performed by dirty coals used under steam boilers, and that too when sufficient provision has been made for draught, and when the stoking is well done. Much heat is also lost by the ash or clinker itself which is cleared from the furnace, often at a high temperature.

To compensate for these losses, namely, imperfect combustion, cooling streams of air passing through the furnace, and the sensible heat carried away by the ash, an extra amount of fuel has to be provided, the cost of which, together with its carriage, and the disposal of the ash, are items which figure not a little in favour of the contention that the ash should be separated as completely as possible from the coal by the process of washing.

The question of coal-washing will become even more important when the better seams of coal are exhausted. At present only the purer seams are being worked, but the time will arrive when it will be necessary to work and use the thin shaly coal, which is now left in the mine. It may be well to remark, by way of supporting this opinion, that the cleansing of coal has forced itself upon the attention of the Belgians, French, and Germans to a much greater extent than it has upon us, and solely because they have not rich pure coal seams.

Fig. 1.

With these observations respecting the results due to the use of pure and of impure coal, it may now be interesting to describe that the manner in which the coal and shale occur in the mine (Fig. 1) renders it extremely difficult to extract the former and leave the latter behind. It will be observed that in the section given, a layer of schist occurs in the middle of the seam, so that there are four surfaces of contact between the coal and its accompanying impurities. The shale adheres to the coal at each of these surfaces, strongly tempting the coal-miner to fill both together into the

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tram. This section would not represent the worst case in practice, but probably a fair average. It is not unfrequent to find a portion of the seam composed of thin layers of coal and shale, which, taken alone, could not be profitably worked; but, in connection with the remainder of the seam, which may be fairly good coal, this schistose coal might be extracted with advantage. Sometimes the thinness of the remainder of the seam renders the working of this shaly portion necessary, in order to get sufficient total height in the workings; and at other times its occurrence in the middle of the seam makes it impossible to avoid extracting it.

In working any seam of coal the object is to obtain as much of the produce as possible, in the form of lump or large coal; but owing to its friable nature, a large percentage of small is made, which frequently is greatly increased by the unskilfulness of the collier. In some of the softer coals the small amounts to 50 per cent. of the whole; in the harder to about 10 per cent. All of this small has to be filled into the tram from the bottom of the mine with a shovel, and is consequently largely mixed with the shale forming the bottom of the mine; nor should it be forgotten that the coal-miner, in using his mandril, cannot avoid reducing some of the shaly top of the stall to small particles, which also get mixed and filled with the small coal.

Having thus noticed the results of using pure and impure coal, and the difficulty of obtaining the coal free from the surrounding and incombustible strata, it will be convenient to turn to the more immediate objects of this Paper, and, in doing so, to describe the manner in which the coal is treated from its first appearance on the pit bank, and previous to washing.

Directly the coal is brought to the surface it is discharged from the tram on to a screen, composed of flat bars placed on edge, at a distance apart varying from $\frac{7}{8}$ inch to 3 inches in the clear, and fixed at an angle of about 26°. The large coal passes over the screen into a wagon placed under the end for its reception, and is, in the case of the better seams, with, perhaps, the exception of a little handpicking, fit for use; but when, as already referred to, the coal and shale are inter-stratified in the seam, the large must be subjected to a process of cleaning. The small, or that portion which passes between the screen bars, contains in all cases by far the highest percentage of shale, amounting frequently to 30 per cent., and is in that state totally unfit for fuel.

All systems of coal-washing depend upon the difference between the specific gravity of coal and that of its accompanying impurities.

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The present methods would be ineffectual if the coal and shale were equally heavy. The specific gravity of shale is in some instances double that of coal, and the two may then be easily separated; but frequently the difference almost vanishes, in which case the problem of separation becomes difficult.

Trough Washing.

The earliest and simplest method of separating coal from its impurities consists in placing the mixture in a current of water sufficiently powerful to carry the coal away, and not powerful enough to carry away the shale.

This primitive system might have been suggested, and may be fairly illustrated by a brook or river transporting pieces of rock, gravel, sand and mud, and depositing them according to their size and specific gravity. The manner in which a stream rolling down a hillside and along a valley deposits its burden of solid matter in the above-indicated order is well known, and shows that the large heavy particles fall to the bottom first, and also that size as well as weight acts as a factor in determining the period of suspension of the bodies. This law holds good along the whole course of the stream. In sedimentary deposits smaller heavy particles occur among larger lighter ones, and still smaller heavy particles among lighter ones not so large, and so on until even among the finest mud is found a trace of the heaviest rock. From this may be deduced the corollary, that in order to separate bodies according to their specific gravities, by means of the sedimentary process in water, the several bodies should be of a nearly uniform size. The trough system, so well arranged at Tredegar, Ebbw Vale, and other places in the district, is a development of this method.

At Tredegar the small coal to be washed, having passed between the screen bars at the colliery in the usual way, is propelled horizontally by an Archimedean screw or creeper into a bunker connected with the timber framing of the "bees-wing" elevator (Fig. 2), which is so arranged that trams placed underneath are automatically filled and elevated by a small stationary engine, having a pair of 8½-inch cylinders, with a length of stroke 15 inches, and geared 3½ to 1, up the inclined side of the triangular timber framing or bees-wing, at the top of which they discharge themselves into a second bunker with hopper bottom. The higher ends of the long washing troughs are put under the second bunker to receive the coal and the water for washing. There are three

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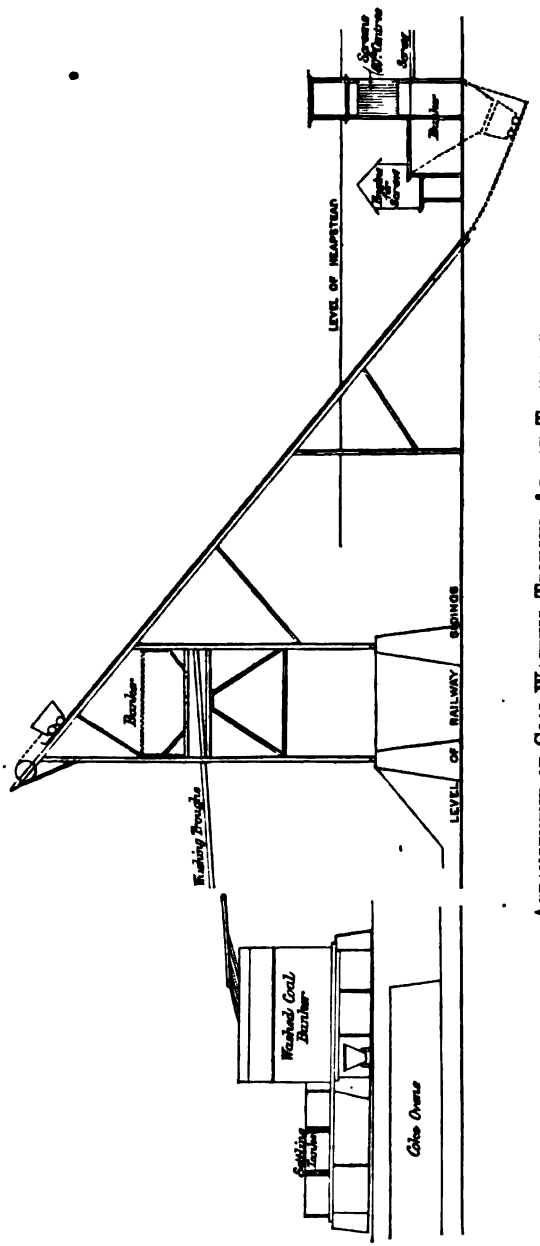
FIG. 2.



ARRANGEMENT OF COAL-WASHING TROUGHS, &C., AT TREDEGAR.
Scale 33 feet = 1 inch.

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such wooden troughs made of 2-inch planking with tapering sides, placed side by side, with a space of 15 inches between each to allow of the material in them being manipulated, and about 250 feet long, 22 inches wide at the top, 18 inches wide at the bottom, and 12 inches deep inside, fixed on timber piers or supports, 20 feet apart, to a gradient of about 1 in 30. The bottoms of the troughs are covered with plates about ¼ inch thick to prevent wear. The water flows in at the head of each trough, together with the coal, which is carried by the stream to the other and lower ends of the troughs, leaving behind on the bottom the heavier shale. To prevent this also being carried away by the water and forming into a heap, there are movable iron barriers sliding in grooves fitted at intervals of about 12 feet, the barriers being 3½ inches deep at the upper end, where the larger pieces of shale are deposited, and diminishing in depth towards the lower end, where they are 1½ inch deep. A number of persons, chiefly women, are employed for the purpose of keeping the coal in motion and exposed to the action of the current of water. The shale is removed periodically by shovels from the bottom of the troughs, and placed alongside conveniently for filling into trams and taking to tip. While this is being done the supply of coal is stopped. Each trough is thus taken in rotation at intervals of about forty-five minutes. At the lower ends of the troughs the coal is partially dried by being passed over short screens before it descends into the bunkers, which are provided with holes in the bottom and fitted with slides, and from which it is taken in trams to the top of the coke ovens. These screens are covered with wire netting of $\frac{1}{16}$ inch mesh, protected by bars ½ inch in diameter and ½ inch apart, through which the greater part of the water passes, taking with it the finer particles of coal into settling tanks. The tanks are constructed of 3-inch planking, about 19 feet long by 7 feet broad and 5 feet deep, placed on the same level with the bunker, and overflowing into troughs leading to a pump, which forces the water back to the head of the troughs to be used over again, being thus kept in continual circulation. Further, the water, with still finer particles of coal held in suspension, which filters or drains away from the bottom of the bunkers and wooden settling tanks, is directed into an open channel, conveying it to settling ponds built of brickwork, about 60 feet long by 10 feet wide and 3 feet deep. There are generally three settling tanks, which are used in the following order: through one the water is being passed, depositing the fine coal; the next is full of deposit, and is drying; while the third is being emptied through openings in the bottom, as in the adjoining bunkers, to be

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ready to occupy the place of the first when that is filled. The contents of the three settling ponds are also removed in rotation about once a month, by trams running on roads conveniently arranged alongside.

The water wasted consists of that taken into the coke ovens with the coal; that lost by leakage and imperfect construction of the troughs, and that filtering away from the bunkers and settling tanks, and in carrying slimes to the settling ponds; but the greater part of the water circulates through the apparatus. The quantity of coal washed by the plant described above is about 200 tons per day of ten hours.

The arrangement at Ebbw Vale differs but little from the one described, and in both places the material dealt with has passed through flat bar screens, about 1 inch between the bars.

The chief objection to this method is, perhaps, that a fair result depends, not upon the regularity of mechanical motion, but upon the assiduity and care with which the operations are conducted by the persons employed. To this may be added inconvenience from frost and rough and wet weather, the work being carried on in the "open" without shelter. The space required is also large, and the cost of labour comparatively heavy; but the former in many instances is not of much importance, and as to the latter, if the results were not so uncertain, little objection could be urged against it, seeing that the first outlay and the permanent charges for interest and depreciation would probably be less than for any system of machine-washing.

It may be safely assumed that this method of coal-washing is characterised by simplicity of construction, economy in first cost, and moderate efficiency when the shale is of such a nature that it may be easily separated from the coal. But the question of cost in any case would appear to be a merely secondary consideration when compared with the increased value of the product. The difference between the value as fuel of clean and dirty coal is such that, although when two processes give equally good results the cheaper would be adopted, still the most important point to be aimed at, within very wide limits as to cost and result, is clean coal. It is not likely that the whole cost of coal-washing, including labour, depreciation and interest charges, with a machine of the highest efficiency, would exceed 4*d.* per ton, and probably the lowest efficiency is not attained without the cost reaching one-half that amount, or say 2*d.* per ton, unless the conditions are exceptionally favourable.

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Conveyance to the Washery.

In the instances mentioned, the washing operations are carried out in the vicinity of the pit; but frequently part of the output from several collieries is dealt with at one and the same place, where it is often found more convenient to select some central position for the purpose.

At Dowlais there are two coal-washing establishments, at some distance from the pits, the coal being conveyed thither in wagons carrying 7 tons each. Two kinds of coal are dealt with, a bituminous or binding coal, and a free-burning or steam coal, in the proportion of 2 of the former to 1 of the latter.

The binding coal is conveyed in end-tipping wagons, whilst the free-burning is conveyed in hopper-bottom wagons; the latter possess some advantage over the end-tipping wagons in the matter of discharging, but have a less carrying capacity in relation to dead weight, and cannot be so conveniently used except with dry small coal. When the doors are opened for the discharge of the hopper-bottom wagon, that portion of the load resting directly upon them falls through; in the case of lump coal and damp small, there is a tendency for the remainder to scaffold, or form a rough arch over the opening, preventing its own descent, and frequently giving considerable trouble to the workmen to effect its discharge. On the other hand, hopper-bottom wagons require no tip or turntable, and may be emptied at any place on a road, which may be sufficiently inclined to allow them to run down-hill by gravity from the full siding to that place, and when discharged to proceed on their journey down-hill to the empty-wagon siding; while in the case of end-tipping wagons a tip has to be provided, and the road cannot be arranged so as to allow the wagons to run down-hill both to and from the tip.

The wagons containing the two kinds of coal having been delivered upon two separate sidings conveniently arranged, with an inclination of 1 in 66, the end-tipping wagons containing the binding coal are run down singly upon a self-acting tipping cradle, and discharged into a screen; and the hopper-bottom wagons containing the free-burning coal are run down and brought to a stand over a similar screen and discharged thereon; the empty wagons are then removed, and are replaced by full ones.

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Machine-Washing.

The several distinct operations connected with the washing of coal by machinery will be treated, and the machinery used therewith will be described, under the following heads: namely, Tipping, Screening, Crushing, Transmission, and Washing; and appended to each section is a particular description of the manner in which the operation is carried out, and of the machinery used, at the new washing establishment at Dowlais, where there is one of Sheppard's machines of five bashes, which washes about 300 tons of coal per day.

Tipping.

The advantage of using end-tipping wagons, in preference to hopper-bottom ones, under certain conditions, has already been referred to, and needs no further notice.

Two kinds of tip are available for discharging heavy wagons of coal with facility: namely, the power-tip, actuated by mechanical means, such as steam or water; and the self-acting tip, which is worked by the loaded wagon itself. The power-tip requires somewhat less height; but where, as is generally the case, the necessary height is obtainable, a well-designed self-acting tip is equal to the power-tip in facility and rapidity of discharge, and has decided advantages in simplicity of construction and in economy of first cost, and therefore is almost universally used in connection with coal-washing.

At the Denain collieries in France, owned by the Anzin Company, a self-acting tip is used for discharging 10-ton wagons sideways. The cradle is supported at each end upon a gudgeon fixed at about the rail-level and between the rails, but on the opposite side of the centre line of the rails to that on which the coal is discharged, so as to give the wagon a turning moment in that direction. As the axis of rotation is much below the centre of gravity of the wagon, the moment of the latter will increase as the angle of inclination increases; the rising side of the cradle is therefore connected to a series of graduated counter-weights, which are lifted successively as the tipping moment increases, and which not only retard the undue velocity of descent of the wagon, but also bring the tip back to its normal position when the wagon is empty. During the process of tipping, the action of the apparatus is controlled by a brake, and the wagon is prevented from leaving the rails by being held firmly between strong adjustable brackets fixed to the cradle.

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The tipping-cradle at Dowlais (Plate 6), consists of a rectangular timber framing, 13 feet long, 7 feet 8 inches wide, and 12 inches deep, covered with timber planking 3 inches thick, upon which a pair of rails with curved-up ends is securely fixed by bolts and brackets. When in normal position, it is placed horizontally over an oblong pit with strong side walls, upon the top of which are two cast-iron plates, one on each wall, well bolted to the masonry. To each side of the framing of the cradle is secured a strong cast-iron bracket, with a curved flange convex downwards projecting from its side. These curved flanges act as gudgeons to the cradle, and bear upon the plates fixed to the top of the side walls. When the cradle partially revolves, as in the process of tipping a wagon, the flanges roll upon the plates which are straight, being prevented from slipping by projections or teeth cast on their underside, fitting into corresponding grooves cast in the plates. In order that a loaded wagon, when on a tip of this description, may turn it from the horizontal position to the required angle for discharge, and that the tip may bring the wagon back from that angle to the horizontal when the wagon is empty, it is necessary that the centre of gravity of the whole mass, tip and loaded wagon combined, should in the former case be some distance in advance of (or nearer to the descending end of the tip than) the centre of gravity of the whole mass in the latter case. This distance must be such that the moments of the weights or forces acting at the centres of gravity in respect to the middle point of the straight line which joins those centres of gravity, shall be somewhat in excess of the frictional resistances of the cradle with its load. The distance between these centres of gravity may be readily adjusted by varying the length of the cradle, or the position of the turned up or stop ends of the rails thereon. It may also be altered by the introduction of weight at the rear or rising end of the cradle when the length is constant and the position of the rails unaltered, or by the three methods combined.

In determining the distance between the centres of gravity mentioned above, a liberal allowance has to be made for the difference between the weights of the wagons, and also of their loads, as well as for the position of the load in the wagon, which is frequently unsymmetrical, and by making that distance sufficiently great, and attending to other points in the design, it is possible with facility to discharge by the same tip wagons varying between 7 tons and 10 tons load.

The segmental gudgeon on which the tip rocks, and upon the position of which its efficiency so much depends, is struck from the

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middle point in the straight line between the before-mentioned centres of gravity, with a radius the length of which depends upon structural considerations. The balance of the cradle would of course be unaltered if a gudgeon of small radius were struck from the same centre, but it would have to be connected by a tall bracket or other similar means, and would have to rest upon a similar bracket secured to the side walls of the pit. Such brackets would, however, be not only costly but extremely inconvenient. It is therefore preferable to use a gudgeon of large radius rolling upon a suitable bearing near the level of the road, which bearing is made straight in order to get rid of the excessive friction that would occur with a concave bearing of so large a radius. To control the tip in the horizontal position, or at any angle, a powerful brake is provided and fixed at its rear end, by which the cradle with a wagon thereon can be held horizontally, and the speed of turning regulated, and when the necessary angle of discharge has been attained, the cradle can be held in that position for the coal to run out. The wagon being discharged, the descent is controlled by the same means.

The process of tipping or of discharging a wagon is performed in the following way: a loaded wagon with the door forward, having been run into position on the cradle while the latter is lying horizontally and securely held by the brake, the iron keys holding the door closed are removed, and a wooden one inserted. The brake is then released, and the cradle with its load automatically assume the required angle of discharge, which in this case is about 50°, the whole being brought quietly to rest and held in position by the reapplication of the brake, the buffers of the wagon having descended upon blocks fixed in the top of the screen. During the latter portion of the descent the coal presses against the door sufficiently to break the temporary wooden key; when the door flies open, allowing the coal to run out on the screen. When the wagon is empty, the brake is again released; and the cradle and wagon return to the horizontal position. A cradle of this description may be designed so as to tip a wagon through an angle of 90° if required, but an angle of 50° is sufficient to discharge completely the most unfavourable coals. When this angle or any greater one is adopted, it is necessary to attach the wagon to the cradle, to prevent the wagon from being thrown over by the velocity it acquires in tipping. The attachment may be simply effected by placing a strong hook with a tee head in the end link of the coupling chain, and sliding the tee head into a suitable bracket fixed to the tip. This arrangement allows the backward motion communicated to

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the empty wagon during its descent after tipping to propel it from the cradle on its return journey from the tip towards the empty-wagon siding.

Screening.

A great portion of the coal which requires washing is too large to be effectually separated from its impurities, or to be raised by the elevators or conveyed by the creepers. This is especially so, when the whole output of a colliery has to be washed, or when the colliery screen-bars are set with a wide space between them, with the view of taking out only the bigger lumps for household purposes. Coal which has passed between the flat bars of a screen 1 inch apart is washed by machinery at Ebbw Vale, and at other places. This may be regarded as the superior limit as to size of coal to be washed, when even moderate efficiency is to be expected, and when it is neither interstratified with shale, nor impregnated with sulphur in the form of iron pyrites. All larger pieces should be crushed; and to avoid reducing that which is already sufficiently fine, it is separated from the coarser material by screening.

Of the various classes of screens used for this purpose, the inclined flat-bar screen, which for simplicity and durability is unsurpassed, is almost universally adopted at the collieries and coal-shipping ports of this country. But it has the serious defect of allowing long wide pieces of shale to pass between the bars; these pieces when very thin are difficult to separate from the coal in the process of washing, and when thick give trouble with the machinery, especially the creepers. If, instead of the bars, were substituted plates perforated with holes of a suitable size, the difficulty with the long wide pieces of shale would be avoided, and a screen almost as effectual in other respects would be obtained.

Mr. Guinotte uses, at the Mariemont Colliery in Belgium, several screens consisting of flat bars; but instead of the bars being fixed and placed at an angle of 25° to 30°, as with the class mentioned above, they receive a swinging motion from eccentrics at one end, while the other is guided in a straight line. The bars are driven in two sets, every alternate bar receiving motion from the same eccentric, or from eccentrics fixed in the same line; while every adjacent bar is driven by eccentrics placed diametrically opposite. The motion imparted to the bars in this way is not only well suited for screening, but is suitable, and is frequently used, for travelling coarse coal in a nearly horizontal direction. But

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the passage of long wide pieces between the bars is inseparable from this system.

A third type of screen is the reciprocating, which may be placed at an angle or horizontally. These screens are suspended by links, or supported on friction wheels, and are driven by a releasing cam. When placed horizontally, the return portion of the stroke is performed by springs; but when inclined at an angle no springs are required, as the screen is brought back by its own weight.

The last class to be noticed is the revolving screen, which is extensively used. Practice differs as to form and construction of these useful screens. They are made either conical or cylindrical. The conical have always their axis horizontal, the difference between the diameters of the two ends giving the necessary inclination to the bottom side of the screen; but the cylindrical are made with the axis either horizontal or inclined at an angle varying between 1 in 16 and 1 in 10. When the axis of a cylindrical screen is horizontal, it is necessary to fix inside the periphery a spiral or screw to travel the coal onwards, as the screen revolves. Revolving screens are frequently made with two shells, both perforated, having an annular space of 6 or 8 inches between, the object of this arrangement being to save length. For the coarser coals, shells of perforated plate, generally of wrought iron, are used; but when the finer descriptions, below $\frac{1}{4}$ of an inch cube, have to be extracted, the shells are of woven wire or gauze. These screens are made of lengths varying between 6 feet and 20 feet, and of diameters from 3 feet to 12 feet, those of the largest diameter being used for extracting the finer coal. The speed of the circumference varies between about 120 feet and 200 feet per minute.

One of the greatest difficulties encountered in screening coal arises from the choking or filling up of the spaces of the screen, owing to the clogging nature of the coal when damp. This is especially so when fine coal is extracted. Attempts have been made, in the case of revolving screens, to overcome this difficulty by causing blows to be delivered automatically by hammers along the top of the screen, so as to dislodge the coal which fills up the spaces. Another arrangement for attaining the same object is to press a wire brush against the periphery of the screen as the latter revolves. Water is also sometimes delivered into the screen with the coal, which renders the material in the more liquid state less liable to choke the spaces.

A method also employed is to place a small pipe immediately over, parallel with, and extending the whole length of the screen, having its underside perforated with small holes. Through this pipe

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steam at a high pressure is occasionally blown. This method effectually clears the screen, but the condensation of steam upon it aggravates rather than reduces the evil it is intended to remove. Compressed air similarly used would probably reduce the evil to a minimum. Very little in the way of clearing the screen can be effected with a reciprocating screen, because the whole screening surface is covered when working. Such screens may therefore be regarded as unsuitable for separating the finer classes of coal.

At the Dowlais new establishment (Plate 6) two screens are used, one for the free-burning, and one for the binding coal, which meet at right angles over a pair of crushing rolls, to which the screens deliver the coarser coal. These screens are of the flat-bar type, similar to, but much larger and stronger than, the ordinary colliery screens, as they have to receive the load of a railway wagon, whereas the colliery screens are supplied by trams. The screens taper in plan, to deliver the coal more conveniently to the crushing rolls. Their principal dimensions are: length, 24 feet; breadth at the upper end, 10 feet, at the lower end, $2\frac{1}{2}$ feet; depth of sides at the upper end, 3 feet, at the lower end, 2 feet; space between the bars, 1 inch; cross section of the bars, 4 inches deep, $\frac{5}{8}$ inch wide above, $\frac{5}{16}$ inch below; angle of screen, 30°.

To add to the efficiency of the screen for the binding coal, the top is formed into a kind of hopper, by fixing at about 8 feet from the upper end a strong plate 5 feet deep across the screen, allowing a space of 18 inches between the bottom of the plate and the bars; this both prevents the coal from being thrown too far down on the screen by the impulse it receives in the tipping, and also causes it to slide along the whole length of the screen bars. A sliding door across the lower end of each screen regulates the supply of coal to the rolls. Under the sloping bottom of each screen is placed a pocket or shoot, into which falls the fine coal that passes through the screen bars. These shoots meet at right angles, and deliver the fine coal underneath the rolls, in the same way as the screens meet over the rolls. All the coal is thus brought to one place, both the free-burning and the binding coal, and is consequently well mixed—a consideration of some importance when it is used for coking purposes. From this point it is conveyed by a short shoot, fixed at an angle of 35°, down to the foot of the elevator.

Crushing.

Before dealing with the question of crushing, it may be well to suggest that the lumps of shale mixed with the coarse coal which

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has passed over the screen may be advantageously picked out by hand previous to its delivery to be crushed. The Author is not aware, however, that such a system is at present adopted as an adjunct to washing.

On the Continent, where less pure coal seams are worked than is generally the case in this country, and where the small coal only is washed, the whole of the coarse is usually prepared for the market by subjecting it to a careful process of handpicking, and the arrangements for the purpose are frequently very complete and convenient. The chief object to be kept in view in arrangements for this purpose is to pass the coal to be picked slowly and in a thin layer before the operatives; which may be effected in several ways. The two following methods are perhaps the best, and are most generally practised. First, by means of a circular revolving table of wrought iron, upon which the coal is delivered from the screen and carried slowly round, while persons stationed round the table examine the stuff and pick out the shale. The other method is to stretch over the circumference of two parallel cylindrical drums, which are in the same horizontal plane at a suitable distance apart, a long, wide, flat endless belt or band of hemp. This belt receives a slow motion from one of the drums, and the whole is so arranged that the coal is conveniently delivered from the screen on to the belt near one of the drums, and is slowly carried before the operatives, who pick the shale out, and is then delivered over the other drum on to a floor, to be filled into wagons.

It has already been noticed that when coarse coal requires washing it is necessary to prepare it for that purpose by crushing. Not only is it difficult to deal with large lumps by the machinery usually employed at a coal-washing establishment, but it is impossible to give the necessary agitation to large lumps in the washing bashes. There is, however, another reason why crushing should be resorted to, previous to washing. Reference has been made to the occurrence of coal in the mine in an interstratified condition with shaly and pyritic impurities. The adhesion between these impurities and the coal, when they occur in this manner, cannot be overcome by the washing process. It accordingly necessitates crushing.

The degree of fineness to which the coal should be reduced depends, therefore, partly upon the capabilities of the machinery, partly upon the amount of agitation that can be given to the water, and partly upon the manner in which the impurities are associated with the coal. Lumps of unmixed coal and of unmixed shale,

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which will pass through a hole 2 inches in diameter, can be separated with facility by washing; but when the shale and coal are interstratified, or when pyrites exists in large quantities in the coal, crushing must be carried to a much greater degree of fineness. No particular limit as to fineness can be stated generally, because that would vary with different coals; but crushing may be safely carried on until no one piece shall consist of both coal and shale.

Coal intended for conversion into coke to be used in blast furnaces is frequently pulverised to a state of coarse powder of about $\frac{1}{16}$ of an inch cube, in order to increase the hardness and density of the coke. This may be, and generally is, done after washing.

For reducing coarse lumps of coal to smaller pieces, the most suitable class of machine seems to be a roller crusher, having one pair, two pairs, or three pairs of rolls, according to the size of the lumps to be reduced; but when small lumps have to be reduced to a coarse powder, experience favours those machines which act by percussion rather than those which act by direct crushing. Of the percussive class of machines, which is extensively adopted for the purpose, Carr's disintegrator and Hall's may be mentioned.

A roller-crusher having one pair of rolls of from 18 inches to 20 inches in diameter and 3 feet long, well fluted with semi-circular flutes about $1\frac{1}{2}$ inch deep, and rounded ridges $\frac{1}{2}$ inch wide, and running at one hundred revolutions per minute, will reduce coal, which has passed through a $2\frac{1}{2}$-inch flat-bar screen, and over a similar screen with 1 inch space between the bars, to a convenient size for washing, at the rate of 30 tons per hour. When coarser coal has to be reduced, containing lumps of 6 or 8 inches cube, such as the output of an ordinary bituminous seam in the South Wales district, two pairs of rollers should be used, one pair over the other; the upper pair, between which the coal passes first, being set about $3\frac{1}{2}$ inches apart and made with coarser flutes so as partially to reduce the coal for the lower and closer pair, which are similar to those of a one-pair crusher. For coal of still larger dimensions, three pairs of rolls are employed.

Instead of fluted rolls, toothed rolls are sometimes adopted when the coal is very large or of the hardest descriptions. In such rolls the teeth, which are pointed, may be cast with the rolls, or they may be made of steel and welded in by fixing them in the mould and running the metal around them, or the steel teeth may be turned and fitted into sockets formed in the rolls. This kind of roll is used in pairs so geared together as either to have the teeth

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of one roll opposite those of the other, or to have the spaces of the one opposite the teeth of the other; or one toothed roll may be used with a plain cylindrical roll, the action in this case being somewhat similar to that of a pick on a floor. A pair of plain cylindrical rolls, varying between 2 feet and 3 feet 6 inches in diameter, and placed almost in contact, is sometimes employed for the purpose of reducing coal to a coarse powder preparatory to coking. Ordinary edge-runners as used in mortar mills are also applied to this purpose; but these are by no means the most suitable machines for this class of work.

To prevent the rolls, or the gearing driving them, from being broken by pieces of iron, parts of old tram-wheels, or sleepers, which sometimes find their way with the coal into the rolls, one of the pair revolves upon bearings placed in slides, and the bearings are held in position by an elastic plunger or buffer, or by a weighted lever (which latter can hardly be so good an arrangement), with sufficient force to crush the hardest coal or shale, but sufficiently yielding to allow a piece of harder material to pass through. The teeth of the gearing should be made of extra length, to permit the necessary lateral movement without becoming disengaged, as that would be likely to result in the fracture of some of the teeth.

Another point requiring attention in designing roller-crushers is the protection of the journals from coal-dust and consequent abrasion. By carefully enclosing the rolls in a casing of wrought or cast iron, having holes fitting accurately around the axis between the journals and the body of the rolls, this object may be tolerably well attained. A reduction of the torsional strains to which the roll-shafts are subject may be obtained by fixing toothed gearing at each end, instead of at one end only as is the usual practice.

A principle too frequently neglected, and which should be regarded in arranging crushing machinery of any description, is that no coal that does not require reducing should be passed through the crusher. In order to carry out this principle, it is necessary to extract by efficient screening the whole of the coal of a finer size than that requiring to be crushed. When two or three pairs of rolls are adopted, screening and crushing should be performed alternately.

The crushers used at Dowlais are of the roller class; each consists of one pair of fluted rolls 18 inches in diameter by 3 feet long, running about fifty revolutions per minute at the new establishment, which is found amply fast enough, as only that portion

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of the 300 tons washed which requires reducing is passed through the rolls. At the old establishment the rolls run one hundred revolutions per minute. The brass steps in which the journals revolve are divided diagonally, and are fitted into cast-iron standards, with steel riders turned down at each end, so as to embrace the tops of the standard, over which they are well fitted, thus giving assistance in cases of unusual strain upon the standard.

A 4-inch shaft is coupled to and drives one of the rolls, motion being communicated from this to the other by a pair of pinions fastened outside the journals. The steps of the roll which receives its motion direct from the shafting are fixed in the standards; but those of the other roll are permitted a lateral motion, being held in position by a strong elastic plunger of india-rubber springs, such as are used on the draw-bars of railway wagons. The journals are made large, the rolls are well encased, and no trouble is experienced from heating of the journals.

Transmission.

Some of the various methods by which the coal is conveyed or transmitted from one part of the washery to another will next be discussed. Of these, transmission by inclined troughs or shoots is the simplest. For allowing small coal to gravitate freely down these shoots, which are preferably made of wrought-iron plates, and thus to avoid the necessity of handling, they should be placed at an angle of not less than 35°. Experience shows that, unless the coal is very dry and hard, the adoption of a smaller angle in order to save height is false economy.

This mode is almost universally used where the distances are short, even though the coal has to be raised for the purpose, it being often found better to prolong an elevator a few feet higher, rather than to complicate arrangements by adding a separate conveyance; but its application is, in all except very rare cases, limited to short distances, owing to the great height required.

Sometimes coal is conveyed into, and away from, the washing machine by water running in troughs, in which case, instead of being at an angle of 35° they have an angle of from 3° to 5°. In this way coal is conveyed from the elevator to the machines, a distance of about 18 feet at the old establishment at Dowlais and at Ebbw Vale, the troughs in both instances being of cast iron, about 6 inches square inside.

Mr. Coppée, in the many extensive establishments designed by him and erected on the Continent, uses this means of transport

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freely, especially with the finer coal below ¼ inch cube, which he conveys from the screens to the washing bashes, and again from the latter to the depositing tank, through distances which, in the aggregate, often amount to 200 or 300 feet. The water for the conveyance of the coal by this method is also used for the washing process, and, as no machinery is required nor extra water consumed, this system seems peculiarly adapted to the applications above referred to.

Vehicular transmission, although not much used within the precincts of a washing establishment, is, nevertheless, occasionally adopted. One case of its adoption has already been described in connection with the washing arrangements at Tredegar, where the coal is hauled in trams to a bunker at the top of the washing troughs. An interesting and extensive application of vehicular transmission has been made by Mr. Marsaut, at a coal-washery in connection with the Bessèges and Molières collieries in France. It has been fully described by him in a communication to the Société de l'Industrie Minérale. An abstract of the Paper was given in the Minutes of Proceedings of this Institution,[1] and subsequently the communication was substantially reproduced in "Engineering," vol. 29. Conveyance by machinery seems, however, to be the most suitable to the requirements of the washery, as it is not limited in its application to short distances like shoots, neither is it intermittent in action like vehicles.

There are several useful machines for transmitting coal horizontally. Of these may be mentioned the Creeper, or Archimedean screw, revolving in a trough; a belt or band similar to that described for handpicking coal; and a carrier, consisting of a plated-chain, of which there are several varieties. For raising coal from a lower to a higher level only one machine has received extended application, namely, the Elevator or Jacob's Ladder.

The creeper is probably the most suitable machine, and certainly the one most extensively applied, for conveying small coal in a horizontal direction, and is used not only for dry or damp coal but frequently for conveying coal or shale in water. Although not so well adapted for raising the material, still there are places where it is used for this purpose. At the Marie Anne and Steinbank Collieries in Germany, a creeper, about 50 feet long, is placed at an angle of about 10°, raising washed coal into a bunker. The object of this arrangement is not so much to elevate the coal as to permit any water mixed with it to drain back out of it.

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[1] Vol. lv., p. 259.

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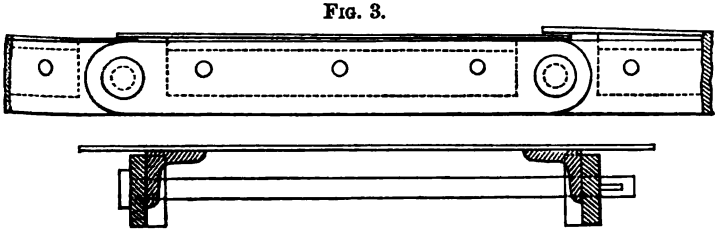
A creeper consists of a square shaft of wrought iron, having journals turned in it at intervals. Upon the shaft is a screw of coarse pitch and very thin thread, in this case called a blade, working in a wrought or cast-iron trough of slightly greater width than the diameter of the screw, having a semi-circular bottom. The end journals revolve in steps fixed in ordinary plummer-blocks, provision being made for resisting the longitudinal thrust of the screw; and the intermediate journals revolve in steps fixed in hangers suspended from the top of the trough. The screw is driven by a pulley or toothed wheel, fixed on the end of the shaft outside the trough, and conveys the coal introduced at one end of the trough to its other end. Although this is a very good contrivance, its use is attended with much friction when dealing with fine coal; and when conveying shale in water the screw-blade wears out rapidly. With a given kind of coal, the quantity conveyed by a creeper depends upon the diameter, pitch, and velocity at which it is driven; but a given creeper will transmit a much greater quantity of coarse coal above $\frac{1}{2}$ inch cube than of fine coal below $\frac{1}{4}$ inch cube. In actual practice a creeper, 14 inches in diameter, 12 inches pitch, running forty-eight revolutions per minute, has conveyed 40 tons per hour of coarse coal; while a creeper 10 inches in diameter, 7 inches pitch, making ninety revolutions per minute, has conveyed only 10 tons per hour of fine coal or duff.

The belt or band has been already described in connection with the process of handpicking, and therefore needs no further mention.

The last kind of machine for horizontal transmission, of sufficiently extended application to require notice, is the Plated-Chain Carrier. Fig. 3 represents a pair of links in one pattern of this

FIG. 3.



ELEVATION AND CROSS SECTION OF PLATED-CHAIN CARRIER.
Scale 1½ inch = 1 foot.

chain, with the plate between them. The endless chain is stretched over a pair of polygonal drums at each end of a frame, and is supported between the drums by rollers or slides, by which it is kept in a nearly straight line. This apparatus cannot be worked

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in water like the creeper, but it can be used for raising coal at a considerable angle; indeed, the Elevator is but a modification of this machine.

The Elevator, for elevating or raising the coal, seems to be an indispensable accessory to a washing establishment, and, when well proportioned to the amount of work required of it, leaves but little to be desired, as it does its work in an efficient manner without any attendance, is durable, and neither difficult nor expensive to construct. The coal is raised in buckets of cast or wrought iron, capable of holding from 20 lbs. to 100 lbs. each, put between and secured at equal intervals to a pair of endless chains formed of flat links, which, for convenience of fixing to the buckets, and for attachment to each other, as well as for giving greater stiffness to each individual link, are placed on edge. Although these chains are sometimes constructed of single links, they are preferably made of single and double links alternately, united by bolts, cottar pins or rivets, which are turned to fit accurately into holes bored near the extremities of the links. The chains, with the buckets attached, are strained over a pair of polygonal drums fixed on shafts, which revolve in suitable pedestals secured to a strong framing. One of the drums is set at a higher level than the other, the difference between their levels depending upon the height to which it is necessary to elevate the coal; the inclination of the elevator is generally 60° or 70° to the horizontal. The uppermost drum is driven slowly by toothed gearing at a speed which should not exceed about twelve revolutions per minute. In some cases the lower drum is used as the driver, but this arrangement necessitates great tension being placed upon the chain in order to prevent the drum from slipping, because the tension produced by the weight of the chain with its load is not here available for keeping the chain in contact with the lower drum; whereas, when the upper drum is made the driver, the weight of the chain with its load is sufficient without additional tension. For facility of fixing the chain, and for taking up any slack caused by wear at the joints, the pedestals of one of the drums have provision for adjusting the distance between the centres of the drums. Where possible, the upper pedestals should be the movable ones, keeping the position of the lower ones fixed, so that the buckets may always pass close to the bottom of the elevator pit, and clear out the coal as it descends from the shoots. From the neglect of this simple precaution great trouble is often experienced in feeding the elevator with coal. In case the gearing makes adjustment at the top objectionable, the plate forming the bottom of the elevator-pit

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should be movable, so that it may follow the bottom drum when that is adjusted. Throughout the distance between the drums, the chains are supported upon angle-iron slides fixed to the frames, or at intervals by rollers; and to prevent the buckets from coming into contact with the slides or the drums, and thus being speedily worn, the links project about ¼ inch below the buckets. This machine is adapted for raising coal or other granular material to heights varying between a few feet and 100 feet, and in quantities suiting the requirements of the most extensive washing establishment; for, although the speed is limited, the buckets may be of any size likely to be required.

Resuming the description of the New Coal Washery at Dowlais, the elevator for raising the coal after it has been crushed is 45 feet long from centre to centre of the drums, and is placed at an angle of 60°. The buckets are of wrought iron (a material which is generally to be preferred) $\frac{3}{16}$ inch thick, and hold, when full, 80 lbs. of coal. The drums are of hexagonal form, and make about six revolutions per minute, the upper one being driven by a toothed wheel, 4 feet in diameter, fastened on its axis, into which is geared a pinion 9 inches in diameter. On the pinion shaft is fixed a pulley 5 feet in diameter, driven from a pulley of the same diameter, fastened on the engine shaft through a flat belt 8 inches wide. The chains are composed of flat links 18 inches long from centre to centre, single and double alternately; the single links are 3 inches by ¾ inch, with thickened ends, and the double links are 3 inches by ½ inch, united together by bolts ¼ inch in diameter; and the chains are supported between the drums by angle-iron slides 3½ inches by 3½ inches by ½ inch, during both their ascent and their descent. This elevator is capable of raising 400 tons of coal per day of ten hours at the slow speed stated above.

The elevator delivers the coal into the upper end of a cylindrical revolving screen, 3 feet 6 inches in diameter, 7 feet long, having an inclination of 1 in 10 from the horizontal, and driven at about twenty-six revolutions per minute. This screen separates the coal into two sizes, the holes in the shell being ¼ inch in diameter. All coal which passes through the holes in the shell, amounting to about 25 per cent. of the whole, is delivered into a creeper 10 inches in diameter, 7 inches pitch, and 60 feet long, driven at about ninety revolutions per minute, and is thereby conveyed to a bunker outside the building, to be taken direct to the coke ovens without having been washed. The coarse coal, delivered from the lower end of the screen, runs down a shoot into a bunker, whence

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it is raised by a second elevator and delivered into a horizontal creeper placed over the washing machine. This creeper conveys the coal and distributes it into the different bashes through openings fitted with slides in the bottom of the trough. The buckets of the second elevator are of cast iron, $\frac{3}{8}$ inch thick, and carry, when full, 25 lbs. of coal. They are attached to chains of single and double links alternately, the single links being $\frac{3}{4}$ inch thick, and the double ones $\frac{1}{2}$ inch, by $2\frac{1}{2}$ inches deep. In this case the links are joined by turned rivets $\frac{5}{8}$ inch in diameter, enlarged in the middle, where they pass through the single link, to $\frac{7}{8}$ inch in diameter. The drums are hexagonal, and the chains with their buckets are guided upon angle-iron slides. The length from centre to centre of the drums is 25 feet, the angle 60°, and the speed about twenty revolutions per minute. The distributing creeper is about 18 feet long, 20 inches in diameter, 14 inches pitch, and is driven at the rate of twenty-five revolutions per minute.

Washing.

The process of washing, or rather of separating the coal by machinery from mechanical impurities, may be effected either by causing an upward current of water to pass through the coal, or by allowing the coal to fall through a great depth of still water. The feasibility of both these methods depends upon the difference between the densities of the materials requiring separation.

Attention to the following elementary considerations will make clear the principles upon which the separation is effected by these methods. If a quantity of coal and shale, consisting of particles of equal dimensions, be thrown into a deep vessel full of still water, the particles of shale will, owing to their greater weight, descend at a higher velocity, and will soon be separated from the particles of coal. Again if, in a vessel having an upward current of water, material of the same description be placed, as all the particles are of equal volume, each will be buoyed upwards by an equal force, which force will communicate a greater velocity to the lighter coal than to the heavier shale, and thus cause them to part company. On the other hand, neglecting the influence of gravity, if the materials to be separated be placed in a downward current of water of sufficient strength, the reverse of the above will take place; that is, instead of the coal being on the top of the shale it will be found underneath, a result due to the greater velocity imparted to the lighter material by the force of the current. When particles of different sizes and of the same density

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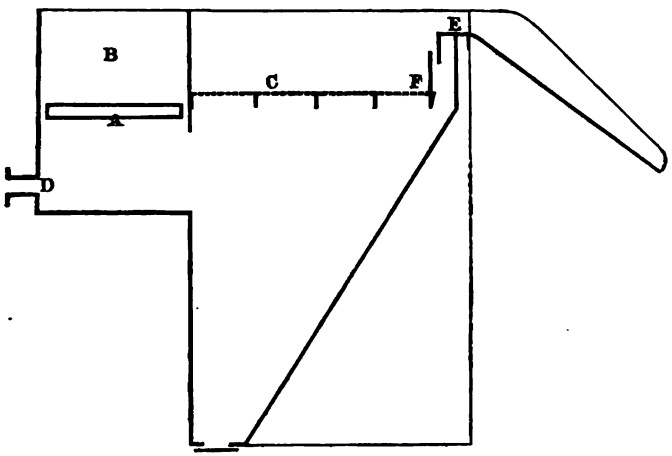
are subjected to these conditions, they will, if similar in shape, be arranged according to their respective volumes, the larger pieces behaving in the same way as the denser pieces mentioned above. It is therefore evidently impossible to effect the perfect separation of coal from the shale by either of these methods, when the sizes of the constituent particles differ greatly, because the same velocity may be imparted in still water by means of gravity, or in an upward current by the force of that current, to a smaller piece of shale as to a larger piece of coal, and they will consequently still continue associated.

Hence it becomes necessary to separate the particles of coal according to their sizes, by some system of screening, previous to the process of washing, which latter, it is to be observed, effects

Fig. 4.



Longitudinal Section of Ordinary Intermittent Upward-Current Washer.

a separation according to their densities, as before intimated. It should also be borne in mind that a downward current, having an opposite effect on the mixed bodies to that which an upward current has, will, if used in conjunction with an upward current, more or less neutralise the effect of the latter, and should consequently be avoided as much as possible.

The manner in which these principles are applied in practice will be understood by reference to Fig. 4, which shows in longitudinal section an ordinary washing machine in which the coal is treated by an intermittent upward current of water. Theoretically, the action of an upward current presents no advantages over that of a fall through still water, in separating the coal from the

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shale; and although Mr. Marsaut and others have proved that the practical solution of the problem can be effected by the latter system with as much simplicity and efficiency as by the former, still the larger part of the coal-washing machinery, both in this country and on the Continent, is constructed on the principle of the intermittent upward current. Mr. Marsaut's machine, for a fall through still water, consists of a cage suspended from the piston of a hydraulic cylinder, the cage having a perforated bottom, upon which the coal to be cleansed is placed to a depth of about 4 feet. The cage is caused to descend by a succession of short drops through still water in a rectangular tank about 6 feet long, 10 feet wide, and 24 feet deep, within which the cage fits with tolerable accuracy. When the cage performs a short descent or drop, it leaves the coal behind, momentarily suspended in the water; the coal then descends by gravity on to the cage, the velocity of each individual particle depending on its density, inasmuch as sizing has of course been effected previously to the washing.

Fig. 4 shows the essential parts of an ordinary machine with intermittent upward current.

The piston A works upwards and downwards in the compartment B, and during the downward stroke forces the water up through the perforated plate C with sufficient velocity to lift the coal and shale to a considerable height. The velocity imparted to the coal is greater than that imparted to the shale, for the reasons already stated; and the tendency therefore is for them to separate. After the piston has reached the bottom of its stroke, the upward current produced by its descent soon ceases; and the particles of coal and shale then fall through the water in the order of their densities, the heavier shale falling more rapidly than the lighter coal. Their complete separation is produced by repeating the pulsation; and when the stroke of the piston is short, the pulsations are often repeated to the extent of two hundred and fifty times. When heavy shale alone is mixed with the coal, it may be easily separated; but when the specific gravity of the impurities approaches more nearly that of the coal, separation can only be accomplished by a long-continued repetition of the operation. To prevent a downward return current from being produced while the piston ascends—which would carry the coal down again among the shale on the sieve, and some of the smaller particles of coal even through the shale—water is frequently admitted at D under a head of several feet to supply that displaced by the piston. With a view to secure the same object, valves opening downwards, are sometimes inserted in the piston, so

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as to prevent the formation of a vacuum underneath as the piston ascends. An alternative method is to make the piston perform the upward stroke more slowly, by driving it either with a suitably-formed cam, or by means of a crank and a block sliding in a slotted lever, similar to that used for giving a quick return motion to slotting and shaping machines, and known as the slot-bar motion. The pulsations imparted to the water not only separate the coal from its impurities, but carry both of them gradually forwards along the whole length of the compartment, and ultimately effect their discharge—that of the coal over the dam E, and the shale through the valve F. Moreover, with a view to assist the motion of the shale towards the valve F, the perforated bottom C is often inclined downwards in that direction. It is the general practice to construct the compartment C—or, as it is called, the bash, in which the washing process is performed—about 5 feet long, from the rear to the dam, 3 feet 3 inches wide, and 1 foot 3 inches deep below the top of the dam, the piston having an area of 5 or 6 square feet, with a stroke varying between 18 inches and 3 inches, and being driven at the rate of from twenty-six to one hundred and twenty double strokes per minute; such an apparatus is capable of cleansing about 5 or 6 tons of unwashed coal per hour. When a long stroke of the piston is adopted, the number of strokes is proportionately less; and of late years the long-stroke piston seems to be gaining favour for washing coarse coal.

It is important that the current of the water be of equal intensity throughout the whole length of the bash, a condition which limits the length to about the above dimension of 5 feet, when the agitating piston is placed at the rear of the bash as in Fig. 4; but if the piston were placed along the side of the bash, the length would not be so restricted. By adopting the latter arrangement of piston, and adding to the length of the bash, a proportionately greater number of pulsations would be given to the coal during its travel along the bash. This plan might be adopted with advantage in the case of coal largely mixed with light shale difficult to separate; and would be simpler and more economical than resorting to double washing, as is frequently done in such instances.

Endeavours have been made to determine, from theoretical considerations, the limit of the difference between the sizes which may be treated together, so as to be compatible with good results; but, owing to the great diversity of forms of the particles, some being nearly cubical while others are thin and flat, no rule of universal application can be established.

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The following Table shows the extent to which classification by screening is carried out in practice at different places, when due attention is paid to efficient washing. These limits of sizes of the material treated in the same bash have been arrived at in each case after an extended experience, and give satisfactory results with the particular class of coal treated.

Meier Iron Works, United States.	Bochum, Germany.		Mr. Coppée, Belgium.	
Inch. Inch.	Millimetres.	Inches.	Millimetres.	Inches.
0·06 to 0·10	0 to 10	0·00 to 0·40	0 to 8	0·00 to 0·32
0·10 „ 0·20	10 „ 15	0·40 „ 0·60	8 „ 14	0·32 „ 0·56
0·20 „ 0·30	15 „ 30	0·60 „ 1·20	14 „ 24	0·56 „ 0·96
0·30 „ 0·42	30 „ 45	1·20 „ 1·80	24 „ 40	0·96 „ 1·60
.. ..	45 „ 70	1·80 „ 2·80	40 „ 70	1·60 „ 2·80

Below $\frac{1}{8}$ inch cube (0·12 inch) the coal cannot well be washed in a machine of the kind above described, neither can it be easily classified by any of the processes of screening already mentioned; and consequently in many instances that portion of the coal less than $\frac{1}{16}$ inch cube (0·06 inch) has been thrown away as valueless, being unsuitable for fuel, and considered incapable of economical improvement by washing.

By a system known in Belgium and France as Coppée's, and in Germany as Lührig's, the finest description of coal may be effectually cleansed. The coal to be washed is mixed with water sufficient to carry it freely down a slightly inclined trough, and is caused to pass through a series of inverted pyramidal vessels on its way to the washing machines. In these vessels the water deposits the coal with a considerable amount of regularity in respect of size, the largest particles falling into the first vessel, and the smallest into the last, while the intermediate vessels receive the intermediate sizes. The different sizes are then washed in separate bashes, as with the larger coal. The washing machines used are of the intermittent upward-current description; the bottom of the bash, instead of consisting of a perforated plate, is in this case formed by a layer of felspar about 4 inches thick on a coarse net of wire cloth, the sizes of the pieces of felspar varying between 1 inch and 2 inches cube, according to variations in the sizes of the coal. Through this porous bottom, which is kept open by the pulsations imparted to the water by the pistons, the shaly

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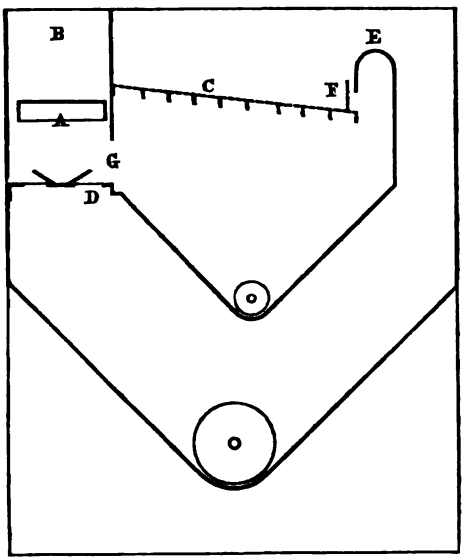
impurities descend into a hutch underneath, and are thence discharged through a valve at the bottom of the machine. The pulsating pistons are of short stroke, from about 1¼ inch down to only ¼ inch, and run at a speed of one hundred and twenty to two hundred double strokes per minute.

Although extensively used on the Continent, this excellent system is comparatively unknown in Great Britain, and, it is believed, has not been adopted in a single instance. It is, as already stated, the only existing system suitable for washing fine coal; and, it may be added, the only one by which coal inter-

FIG. 5.



LONGITUDINAL SECTION OF SHEPPARD'S INTERMITTENT UPWARD-CURRENT WASHER AT DOWLAIS.

stratified with shale, or containing iron pyrites, can be washed effectually, inasmuch as these kinds of coal must be finely pulverised before it is possible to remove their impurities by washing.

Sheppard's machine erected at Dowlais, and set to work in the beginning of 1881, has five bashes, and deals with about 300 tons of unwashed coal per day of ten hours; it is represented in longitudinal section by Fig. 5. By means of a creeper 20 inches in diameter, placed over the machine, the coal is fed into the rear end of the bashes, which are 5 feet long by 3 feet 3 inches wide; and by the pulsations imparted to the water it is conveyed

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forwards along the whole length of the bashes, and is discharged over the dam E, whence it falls to the bottom of the lower hutch, along which the coal is conveyed by a second creeper to one side of the machine, and is raised thence by an elevator, which delivers it into a bunker outside the building. The shale, with the other impurities separated from the coal, passes through valves F immediately under the dam; these valves, extending the whole width of the bashes, are lifted at intervals, and discharge the shale into an inner compartment extending the whole width of the machine; the shale is thence conveyed by a third and smaller creeper along the bottom of this compartment to the side opposite that to which the washed coal is carried; it is thence raised by an elevator and delivered into a shoot, from which it is taken by trams to the rubbish tip. The water in each bash receives pulsations from a rectangular piston A, 2 feet by 3 feet 3 inches, having a stroke of 1 foot; the piston is driven by a crank at the rate of thirty-two double strokes per minute, the velocity of the up and down strokes being equal. The bottom of the bash is formed of a copper plate C, 19 B.W. G = 0·04 inch thickness, perforated with holes of $\frac{3}{32}$-inch diameter, and about sixty to the square inch; and supported by a cast-iron grating, the bars of which are $\frac{3}{4}$ inch wide, 2 inches deep, and form spaces 15 inches wide by 6 inches long. Angle-irons are riveted to the side plates of the bashes for the whole length of the bash, and upon these the grating with the perforated plate is bolted, having a downward slope from the rear to the dam.

This machine, illustrated in Plate 4, is of the intermittent upward-current type; but instead of a portion of the water being discharged from the machine at each pulsation, it is delivered into the lower compartment with the washed coal; the piston in ascending draws the water up from this compartment through a foot-valve D beneath, and at the top of the stroke the valve closes; in descending, the piston forces the water upwards again through the unwashed coal in the bash. In this way an intermittent circulation of the water is kept up in one direction only, with but little downward return current through the sieve. Formerly a valve was used in the opening G from the piston hutch into the washing bash, with the view of preventing return of the water as the piston ascends; but this valve has been found unnecessary. The machine is driven by a pair of vertical engines with cylinders 10 inches by 18 inches stroke, making seventy-two revolutions per minute. A continuation of the crank-shaft is carried upon a suitable frame across the whole width of the machine, and has fixed upon it the

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necessary pulleys and toothed wheels for driving the elevators, creepers, and piston cranks. The elevator raising the washed coal out of the machine is similar to that previously described for delivering unwashed coal into the machine; except that the cast-iron buckets are here made long and shallow, and are perforated with numerous holes to allow the water to drain from the coal as it ascends. It is driven from a 4-foot pulley fixed on the crank-shaft, connected by a 6-inch leather belt to a 3-foot pulley at the head of the elevator frame; on the same shaft with the latter is a pinion 7 inches in diameter gearing with a 3-foot wheel on the drum-shaft of the elevator, which therefore makes about nineteen revolutions per minute. The bottom hexagonal drum of this elevator is fastened on the end of the axis of the large creeper which works in the bottom hutch of the machine, and to which motion is thereby imparted. The shale elevator is similar to, but smaller than, the washed-coal elevator, and drives in the same way through its lower drum the shale creeper working in the bottom of the upper hutch. The shale apparatus is large enough to carry away shale amounting to 25 per cent. of the unwashed coal delivered into the machine.

This machine seems to be well adapted for washing coarse coal containing little or no "duff," and occupies less space for a given capacity than any other known to the Author, and in the matter of cost compares advantageously with other systems. With suitable coal the water is not changed, except when the machine is cleaned out, which would be at intervals of from once a week to once a month; and consequently no settling ponds are required.

At Dowlais, however, settling ponds were made, owing to the large amount of fine stuff in the coal. The fine is now extracted by screening previous to washing; but the ponds are still used to some extent, and a considerable quantity of pyrites is deposited in them. With respect to this machine it must be stated that a considerable reduction of the speed at which some of its parts are driven, especially the elevators, would be an improvement, and would diminish the wear and tear.

There is also at Dowlais another washing establishment (Plate 5), which was erected some fifteen years ago, and at which there are two "Bérard" machines of four bashes each (making eight bashes altogether), placed back to back, with the elevator between them, the two machines together being capable of treating 480 tons of unwashed coal per day of ten hours. The same descriptions of coal are dealt with as at the new establishment, and in a similar manner, except that the whole of the fine is washed here.

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A vertical engine, 16 inches by 16 inches length of stroke, making eighty revolutions per minute, drives the whole of the machinery, which consists of the two washing machines, a pair of crushing rolls, and an elevator for raising the coal. On the crank-shaft of the engine are keyed three pulleys, of which one pulley 8 feet in diameter drives the rolls at one hundred revolutions per minute, and by means of a 3 feet 6-inch pulley attached to one of the rolls, and reducing toothed gearing, gives motion to the elevator, the hexagonal drums of which make five revolutions per minute. The other two pulleys are each 5 feet 6 inches in diameter, and are connected by belts to pulleys 4 feet in diameter on the agitator shafts of the washing machines, which they drive at ninety-five revolutions per minute. Motion is imparted to the pistons from the shafts by straps and eccentrics of cast iron, and wrought-iron forked rods, the length of stroke of the pistons being 3 inches.

The coal to be washed is discharged from the wagons into shoots having short screens, which take out some of the small. From these shoots it passes through the rolls, where it is crushed; and it is then elevated by an ordinary bucket-elevator between the machines. The elevator raises and delivers the coal into the upper limb of a ⅄ shaped shoot, which divides it into two portions, and conveys it into troughs fixed at a slope over the machines, down which the coal is conveyed by water and delivered into the rear end of the bashes. The coal, having been washed, is discharged over the dam of the machine with the water into a short inclined shoot, the bottom of which is made of wire cloth, to allow the water to drain from the coal, while the latter runs down into a tram under the end of the shoot. A large quantity of fine coal and slimes pass with the water through the wire cloth; the fine coal is intercepted as completely as possible by sieves fixed in wooden troughs, along which the water passes on its way to the settling ponds, where the slimes are deposited. There are three settling ponds, 40 feet long by 25 feet wide and 3 feet deep; they are used in succession.

In this machine the shale leaves the bash through a valve under the dam, and falls into a hutch beneath; from thence it is periodically run out into trams below, through an opening in the bottom fitted with a slide, to be taken to the rubbish tip.

Ebbw Vale Washing Establishment (Plate 5).

About eight years ago the Ebbw Vale Company erected at their Works extensive machinery and plant for washing coal to be con-

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verted into coke for use in blast furnaces. The coal is brought to this establishment, after having passed through flat-bar screens with 1-inch spaces, in end-tipping railway wagons of various capacities from 4 tons to 10 tons load. These are discharged into a bunker automatically by a tipping cradle similar to that described in connection with the new washery at Dowlais, except that the cradle has in this case to be brought back to the horizontal position by a winch when the wagon has been emptied.

The coal is raised from the bunker, into which it has been tipped from the wagons, by a bucket-elevator of ordinary construction, the drums making twelve revolutions per minute; the elevator delivers the coal into inclined troughs, along which it is conveyed by water and fed into the machines in the same way as at the old establishment at Dowlais. The washed coal is discharged from the machines on to a fixed inclined screen composed of wires $\frac{1}{16}$ inch in diameter, and $\frac{1}{16}$ inch apart; the screen is 7 feet long, and extends the whole width of the machines, which allows the water to drain fairly well from the coal. Under the lower end of this screen and parallel with the ends of the machines is a creeper 14 inches in diameter, of 12 inches pitch and 24 feet long, making forty-eight revolutions per minute, into which the coal falls from the screen, and by which it is conveyed to a second elevator similar to the former. This elevator raises the washed coal, and delivers it into a large cast-iron bunker outside the building; through openings in the bottom of the bunker, fitted with slides, it is run out into trams and conveyed to the coke ovens as required. From the bashes the shale is delivered continuously through an opening under the dam in each bash, fitted with two sliding valves, into a creeper in front of the machines, which conveys it to the bottom of an elevator at one side of the machines, to be raised and delivered into trams.

At this establishment there are four single-bash machines, the bashes being each 6 feet 10 inches long, by 4 feet 10 inches wide, and the four together capable of treating 400 tons of unwashed coal per day. The pistons are rectangular, 4 feet by 2 feet, having a stroke of 18 inches, and making twenty-six double strokes per minute. Water is admitted into the machines under the pistons, through two 4-inch pipes in each machine, under a head of about 27 feet, from a large tank covering the whole of the top of the building; there is accordingly a continuous upward-current of water through the coal in the bashes, and the current is intensified by the descending stroke of the pistons, which have rectangular holes without valves to prevent the formation of a vacuum under-

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neath as they ascend. The bottom of the bash in which the coal is washed consists of flat bars on edge, $\frac{3}{16}$ inch apart, their ends resting upon ledges cast on the back and front plates of the bash. This is a more durable and less expensive bottom than the perforated copper plate on a cast-iron grating of the other machines described previously; and where, as in this case, there is a continuous upward-current of water to prevent fine coal from being drawn down through the bars, there seems to be but little objection to its adoption. It should be observed, however, that the proportion of clear spaces to the solid bars is less than with the perforated copper plate, and that the friction of the water passing up between the comparatively deep bars must be greater.

An endeavour has been made to select only the most successful methods of operation, and the most approved machinery used in the process of washing coal, for description and illustration in this Paper. Much of interest has no doubt been omitted; but it is believed that what has been given may prove useful and interesting to those immediately engaged, or even indirectly concerned, in the important question of the purification of fuel. The Author regrets that he has been unable within appropriate limits to deal more comprehensively with the excellent system of Mr. Coppée, or to notice other systems which have been adopted in Belgium, France, and Germany, where coal-washing is completely and skilfully performed, systems which in themselves specially considered would form the subject of an interesting paper. For the same reason the consideration of the results of washing has also been avoided, as a topic which could not be treated with any degree of thoroughness without in some degree ignoring the main object of the Paper; but it may be stated that each of the systems here particularly described as in use in South Wales is equal to the extraction of about 6 per cent. of ash by one process of washing. This is, however, by no means the limit to which the separation may be effected; for, in Continental practice, coals containing 17 or 18 per cent. of ash have in many instances as much as 14 per cent. removed by washing.

In conclusion the Author wishes to acknowledge his indebtedness to Mr. John Vaughan, who has unreservedly placed at his disposal the information which he has acquired during an extended experience in connection with coal-washing.

The Paper is illustrated by several drawings, from which Plates 4, 5 and 6, and the woodcuts have been prepared.

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Discussion.

Mr. E. P. Rathbone said that during the last three years he had taken every opportunity of visiting the largest coal-washing establishments in Belgium, Germany, and France. He had himself written a Paper for the North of England Institute of Mining Engineers on the "Lührig Method of Coal-washing."[1] He held that the chief cause of the perfection of Continental systems was the irregular character of the coal seams, which rendered the coal very brittle, and also the large intermixture of "dirt," or shaly matter, which it was most difficult to get rid of. In the Lührig and the Coppée systems, the great point was the successful treatment of the fine "smudge" coal, which at English collieries was often wasted. In one Continental establishment the treatment of the entire coal output was of such an efficient character that the waste of coal was reckoned at 2 per cent. only. He knew of a colliery in England where thousands of tons of this "smudge" were lying wasted, and the manager had asked him whether it would be possible to make patent fuel from it. He had arrived at the conclusion that it was not only possible, but, should the price of coal again go up, it might be made a very profitable industry. Mr. Rathbone.

The treatment of "smudge" was effected, on the Lührig system, by means of "Spitzhästen" (grading boxes of pyramidal shape) and continuous-bed jigging machines, exactly similar in construction to the "continuous Hartz-jigger," so much used in Continental ore-dressing establishments for the treatment of fine slimes. In the Lührig jigger, as described by the Author, there was a bed of small pieces of felspar, about 3 inches or 4 inches thick, laid on the top of the sieve, against which the water below was made to pulsate by means of a plunger. The water being forced up against the underside of the sieve, raised the felspar at each pulsation (the piston making 150–170 strokes per minute, ½-inch stroke), allowing the impurities, which were of about the same specific gravity as the felspar, to pass into the hutch beneath, whilst the coal, being lighter, passed over the top of the sieve. Without this bed of felspar it would be impossible to treat "smudge" coal, as the mesh of the sieve being of necessity very fine, would soon get choked. At one of the establishments where Lührig's system was at work, Mr. Rathbone was assured that

[1] Transactions of the North of England Institute of Mining and Mechanical Engineers, vol. xxix., p. 159.

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Mr. Rathbone. the coal, which before washing was associated with 25 per cent. of impurities, afterwards contained only from 5 to 6 per cent., the cost of the operation being very moderate. He considered that some modification of the systems of Mr. Lührig and of Mr. Coppée might be introduced with advantage into districts in England where the coal was impure, and would certainly be far superior to anything known in England at the present time.

Mr. Bewick. Mr. T. J. BEWICK said his experience of washing minerals had been principally confined to the dressing of lead and other metalliferous ores. He knew a little of Mr. Sheppard's machine, and his experience of coal-washing led him to believe that it was an excellent one. Certainly, as regarded economy, it was valuable, and in some cases he believed the cost was even lower than that mentioned in the Paper. In one colliery in the county of Durham, where a considerable quantity of small coal was washed to make coke, he was informed that without washing it was impossible to make saleable coke. The cost, including labour, wear and tear, interest on capital, &c., was only $1\frac{1}{2}d.$ per ton. Another advantage in Mr. Sheppard's machine was that it was compact, and used a very small quantity of water, which was an important consideration, because at many collieries water was scarce, and, where plentiful, in flowing off it interfered with the stream into which it fell, and then proceedings were likely to be taken by the River Conservators. The mode of placing felspar on a grating or sieve was similar to that adopted in lead-ore washing. The ore could not be washed clean without the intervention of a "bedding," that was, pieces of lead ore of a considerably larger size than what passed through the apparatus. The bed had to be frequently renewed, because the lead ore, being friable, wore away. Of course the valuable product in lead mines was that which went to the bottom, but, in the case of coal, it was the reverse. He could imagine many instances in which a considerable economy might be effected by a modified arrangement at the top of the pit in connection with the machine. Now the first object appeared to be to deposit the coal at a low elevation, then raise it to a moderate elevation, next pass it through the sieve, and then elevate it again for the purpose of loading into wagons. If it could be arranged on a hillside a great deal of the machinery that was used, and hence a great deal of the capital, would be rendered unnecessary; a considerable amount of wear and tear, too, would be avoided, and the result would be shown in a cost of so much less per ton.

Mr. Wynne. Mr. T. WYNNE said he did not think he could add anything to

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the discussion. His experience had been more in connection with getting coals, than washing them. Mr. Wynne.

Mr. JOHN ROGERSON said the difficulty of coal-owners was to supply coke that could be used by manufacturers of iron. The manufacturer had a chemist to find out how much ash there was in his coke and how much sulphur. For that reason since 1872 it had been difficult to supply such coke to the iron manufacturers as would please them. So long as they worked the best seams it would not be difficult to make good coke with 3 or 4 or 5 per cent. of ash and 0·50 per cent. of sulphur. But as for some time the produce had to be mixed with that of inferior seams, it was necessary to adopt some means to purify the coal from sulphur and ash. Since the West Thornley coke had been washed there was on an average from 5 to 5·5 per cent. more carbon. This was available in the blast furnace for smelting; consequently a less quantity of the washed coke would be required. The coke was also much more free from sulphur, and therefore produced a purer quality of pig. He desired to lay before the members the following analysis of coke that had been made from washed and unwashed coal:— Mr. Rogerson.

[*Copy.*]

The Weardale Iron and Coal Company (Limited),
Tudhoe Iron Works Laboratory, Spennymoor,
8 May, 1882.

John Rogerson, Esq., Croxdale Hall, Durham.

Dear Sir,—The following are the results of my analysis of samples of coke made from "washed" and "unwashed" coal at our West Thornley Colliery.

	Average of eleven Samples made from Mixed Coal washed.	Average of eleven Samples made from Mixed Coal unwashed.
Carbon	89·74	84·39
Sulphur	0·83	1·22
Ash	9·18	13·92
Moisture	0·25	0·47
	100·00	100·00

	Coke from Coal washed.	Coke from Coal unwashed.
Carbon	89·53	77·80
Sulphur	0·82	1·17
Ash	9·35	20·87
Moisture	0·30	0·16
	100·00	100·00

I am, dear Sir,
Your obedient Servant,
(Signed) A. B. COWAN, Chemist.

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Mr. Jones. Mr. BENJAMIN JONES said the question was a very complex one. The washing of coarse coal could be done with tolerable ease by almost any of the machines to which allusion had been made, but there was a great difficulty with regard to the finer kinds of coal that would pass through a sieve with ¼-inch holes. He was not prepared to say what was the best way of dealing with the subject; but the Lührig and the Coppée machines, in which the coarse and fine coals were treated separately, and in a different manner, appeared to him to meet the difficulties of the question far better than any other machine he had seen at work.

Mr. Cochrane. Mr. WILLIAM COCHRANE, said it appeared to him that the question of washing was one only to be considered where there was a large percentage of ash and shale. When coal contained 3 to 4 per cent., as in the North of England, he questioned whether the washing process was required, and whether the process of abstracting the shale by handpicking was not the best. If the Author had worked out the economy of washing such coal, instead of showing the difference between a 5 per cent. and a 15 per cent. of ash quality, he did not think that the result would be found to repay even the small cost of 1½*d.* or 2*d.* a ton. The elaborate process of washing such coals would not be required if more care were taken in the separation of the shale upon the screens. He had adopted the principle of endless bands, formed of steel plates carried by an endless rope about 30 feet long, passing nearly horizontally before six or eight operators, the coals being made to travel in a very thin stratum, so that the dirt could be well picked out before it went to the crushers. He thought that method was attended with the largest economy in the case of coals used for the production of coke. With reference to the washing of coal for generating steam he had not heard of anything of that kind being done satisfactorily. It was impossible to get rid of the fine pyrites by picking it out. He had confined his observations to shale, which he understood to be the special object of the Paper.

Mr. Marten. Mr. H. J. MARTEN said his experience with respect to coal-washing was limited. A few years since he had occasion to inspect some coal-washing machines in operation at Wigan, where a large amount of "smudge" had accumulated at one of the principal collieries. This "smudge," in consequence of the impurities contained in it, consisting of dirt, pyrites, and shale, had, prior to the introduction of the washing-machines, not only no commercial value, but the accumulations of it had become a positive encumbrance. An enterprising man, the late Mr. James Morrison, of Newcastle-upon-Tyne, who was familiar with the

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process and advantages of coal-washing as conducted on the Continent, purchased these accumulations of "smudge;" set up washing-machines similar to some of those described in the Paper, removed by these means the great bulk of the impurities, and was rewarded by producing a clean "residuum," from which a coke of fine class was manufactured. In this instance the washing-machines practically became the commercial substructure for the large blast furnace plant which had been erected there within the last few years. Mr. Marten's object in inspecting the washing-machines at Wigan, was the application of the same process to the small coal, or "slack," of the South Staffordshire district. The practical result of his experiments with that material was not satisfactory. Large quantities of shale and pyrites were undoubtedly removed from the fine "slack" or "smudge," but the attempt to convert the clean "residuum" into coke failed, as it was not sufficiently bituminous to coke, and burnt away into ash. He considered there were numerous descriptions of bituminous coals to which the system of machine washing might be advantageously applied, but there was no corresponding advantage, as far as he could judge, from its application to non-bituminous, free-burning small coal. It should also be remarked that, in bituminous small coal, the washing produced a much more satisfactory result where the sulphurous element was concentrated in the shape of pyrites, than where it was chemically diffused through the entire substance of the coal, as in the latter case only a fractional portion of the sulphur was removed. This was the case with one of the inferior measures of coal known in Staffordshire as the "stinking" coal, which was so loaded with diffused sulphur that its fractured side, when exposed to the air, frequently became covered with all the colours of the rainbow. Within the limits named, the washing of bituminous "smudge" was undoubtedly of great commercial advantage, as by that means a waste and cumbersome by-product was converted into one capable of inaugurating and profitably sustaining important industrial enterprises. Mr. Marten.

Mr. E. Williams asked whether it was not possible to clean coal without the use of water? Wetting the coal was a great evil, and the very small coal was converted into mud. Might not the difficulty be met by using compressed air, which he thought need not be more costly than water? Mr. Williams.

Dr. W. Pole thought it was worth consideration whether any process of the kind now under discussion might be of use in preparing coal for the manufacture of gas. Everyone connected with gas knew the great difficulty of freeing it from sulphur. Dr. Pole.

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Dr. Pole. Some years ago a London manager tried the experiment of picking the pyrites out of the coal, with, it was believed, a reduction of the impurity. If washing would effect this object it might be worth a trial.

Mr. Hawksley. Mr. T. HAWKSLEY, Past-President, said that fifteen or twenty years ago, when the washing of coal was first introduced, those who were interested in the manufacture of gas were induced to pay some attention to it. The result was that the coal was no doubt rendered physically cleaner, but its chemical constituents remained unchanged. The coke was better because it was not mixed with earthy matter. What was called "ash" in the Paper was, he apprehended, in the main nothing more than earthy matter, which was, as it were, painted over the coal, and which did not form any part of its chemical constituents. Nor was any change produced in regard to sulphur. If coal were picked, and the heavy particles of iron pyrites removed, no doubt there would be to some extent a reduction in the amount of sulphur evolved as sulphuretted hydrogen, which was easily removed in gas-making by lime or oxide of iron; but with regard to almost all other compounds no change would be made. The other sulphur was combined with the coal so intimately that no washing would remove any of it; these compounds remained, and were passed on to the community, unless, as in the best gasworks, they were as far as possible intercepted by lime purification. Gas companies therefore did not as a rule care very much to restrict their purchases of coal to the washed material, as the additional cost would be more than any amount that could be saved by its use.

With regard to the Table put in by Mr. Rogerson, he had to remark that, as a rule, chemists' returns were very delusive when they were not made comparative. The reason was that the chemist always dealt with percentages. It was stated, for instance, that in one hundred parts of unwashed coal the percentage of carbon was 84·39, and in washed 89·74, so that it seemed as if carbon had been actually put into the coal, which was an absurdity. The chemist took so many parts, say one hundred, of unwashed coal, and found in it eighty-four parts of carbon; he then took the same number of parts of washed coal, and found eighty-nine parts of carbon; but he did not give the loss in weight sustained by the washing. He commenced with, say, 100 grains of unwashed coal; whereas he was only operating perhaps upon 90 or 80 grains in the washed state, and therefore the return was delusive. The question was, supposing 100 tons to be brought to the machine, how much there would be left to sell. There might only be

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80 tons, in which case there was a loss of weight of 20 per cent., of which the chemist took no note. The return therefore was merely a scientific expression, without any commercial value. Mr. Hawksley.

Mr. W. Atkinson said no allusion had been made to the value of coal-washing machinery for purifying coal for locomotive purposes. When the Isabel Segunda Railway was opened in 1858, he examined various seams of coal at the Orbo mines, and it appeared to him that there was only one seam available for locomotive purposes. Since that period the North of Spain Railway Company had purchased those mines, and they now used 80,000 tons of coal a year, which they washed and formed into bricks by mixing it with bituminous matter. In that case the whole value of the material depended upon the washing. He presumed that much the same kind of thing obtained in Belgium, where large quantities of stacked bricks might often be seen near the locomotive depôts. Mr. Atkinson.

In 1855 the late Mr. H. F. Mackworth, M. Inst. C.E., recognising the importance of coal purification and the imperfections of the methods then in use by "jigging," in which the downward movement was prejudicial, patented a machine with a continuously ascending current, the velocity being capable of regulation according to the relative specific gravities of the coal and of its impurities. He claimed a more effectual separation, a saving of coal, an economy of power and manual labour, a saving of water, and a greater dryness of the washed coal, than had been previously accomplished. The coal was fed by an elevator to a receiver, there meeting the ascending current, which carried the coal on to a strainer, whence it was swept by a revolving brush into a wagon, the impurities descending to a lower chamber and being raised by an elevator to a wagon. The water, which was used over and over again, was actuated by a centrifugal pump. After a trial at the Ashton Vale Colliery near Bristol, from 1858 to 1860, the proprietor certified that the coal was purified very effectually. The Messrs. Fletcher, who were using the machine day and night, producing 50 tons of purified coal in twenty-four hours at a cost of 2*d.* per ton, and extracting 30 per cent. of impurities from the coal delivered to the machine, certified that the machine accomplished its work without any appreciable waste of coal, and that it was by far the most efficient machine before the public. It would appear that Mr. Mackworth's machine was a new departure in coal-washing, and had led to further improvements.

Mr. J. L. Thomas said, in dressing lead ores handpicking was Mr. Thomas.

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Mr. Thomas. employed as a preliminary process to a great extent, and he thought that with many descriptions of coal a similar process might with advantage be applied for the removal of iron pyrites and shale. Crushing coal, which was in most cases very friable, was, he considered, to be avoided if possible, as crushing gave rise to the formation of a large percentage of coal dust and consequent loss in the resulting sludge. He was not aware that in this country the coal was recovered from the sludge by any after-process. The cost of washing a ton of coal appeared to vary from say 1½*d.* to 4*d.* per ton, and if this cost was not to be exceeded, he did not think any after-process for recovering the coal from the sludge could be carried very far. Pneumatic processes had been propounded in various instances for dressing metalliferous minerals, and he considered it quite feasible that some adaptation of them might be applied with advantage to the extraction of pyrites from coal, and possibly the resulting pyrites would have a commercial value. The question was, could coal be dressed by a pneumatic process at a cost that would pay the coalowner? Allusion had been made in the Paper to the coal clogging in the grates. He would ask whether the grate bars were usually made taper, so that if the opening for the passage of the coal on the top side of the grate were 1 inch, it would be, say 1¼ inch, more or less dependent on the depth of the bar, on the under side.

Mr. Bewick. Mr. T. J. Bewick said there was a commercial, as well as a chemical, aspect of the analyses given by Mr. Rogerson. When people bought coal, they did not want shale or pyrites intermixed therewith, but only carbon. Pure coal would fetch a higher price than coal mixed with the impurities referred to by Mr. Hawksley. The question of carriage was also an important consideration, because coal worth 10*s.* a ton cost no more to carry than coal worth only 5*s.* It was the same with lead ore. A manufacturer did not want to buy moisture or quartz, or other mineral or rubbish, but lead ore only. The inferior article of course fetched a less price.

Sir F. Bramwell. Sir F. Bramwell said Mr. Hawksley did not dispute that; his objection to the analysis was that it seemed as if by the washing 5 per cent. of carbon had been added.

Mr. Hawksley. Mr. T. Hawksley said the results did not give the loss. It was assumed by the chemist that in one hundred parts of coal there were certain percentages of the four elements in question. When a certain quantity, not stated, was washed, he proceeded to analyse the washed coal, assuming in that also one hundred parts, from which other percentages were obtained. It was necessary to

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know how many parts had been taken to make up the quantity lost before any commercial result could be deduced. Mr. Hawksley.

Mr. J. ROGERSON said, in the first place he attempted to sell coal manufactured into coke from unwashed coal as a commercial article, and sent it, say, to Mr. Williams, who would not have it at any price. To get out of the difficulty he had to resort to a process which would enable him to sell his coke. With that view he gave samples to his chemist for analysis—the same quantity washed and unwashed. It was quite true that 100 tons of unwashed might only produce 94 tons washed;[1] but while the unwashed article was not saleable, with the other he could manufacture coke that could be sold for 10*s.* a ton. The machinery was used for the purpose of producing a saleable article. Mr. Rogerson.

Mr. W. RICHARDSON said the operation of washing coal was far more important than was generally imagined. He had no doubt but that the system had been resorted to on the Continent before any attention was paid to it in this country, in consequence of the coal there not being in general so pure as English coal, particularly Durham coal, from which field the greatest quantity of English coke was made. One seam in that district was very free from dirt, but it was now becoming exhausted. The remainder of the seams contained more dirt, requiring the coal to be washed to keep up the quality of the coke. The coal from all other fields also required washing to produce good coke. The new contrivance which had been referred to as an improvement, through requiring little water—the same water being used over and over again—was such that any clayey matter in the coal was mixed and churned with the water, and this dirt adhered to the particles of coal and was carried away with them. This left the coal in a less clean state than when operated upon by the other machine, where more water was used, and the dirt could float away. The greatest difficulty was experienced in separating the pyrites from the small coal, as, in the case of many coals, sulphur was so intermixed that unless the coal was crushed it could not be separated. On the Continent Mr. Richardson.

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[1] Coke made from "Black Prince Coal" as produced from the mine—

Carbon	94·55
Sulphur	0·65
Ash	4·50
Moisture	0·30
	100·00

J. R.

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Mr. Richardson. the coal-washing industry was far in advance of what it was in England.

Mr. Harvey. Mr. THOMAS F. HARVEY, in reply, said that the object of the Paper was not to introduce any particular machine, but rather to draw attention to the importance and difficulty of the subject. The class of machine would be determined by the character of the coal to be washed. If, like Durham coal, which did not require washing, no machine would be needed; but in dealing with dirty coal, like that on the Continent and elsewhere, as referred to in the Paper, especially the fine, and such as was impregnated with iron pyrites, a complicated machine must be used, or the coal be allowed to remain uncleaned. He did not agree that Sheppard's machine used less water than machines on other systems, because in any case the water might be circulated by a pump. Neither could he admit that because the water was not continually discharged from the machine, the machine was a retrograde step. Washing coal, as usually practised, was not a cleansing of the lumps of coal from any particles of dirt that might adhere to them, but rather a separation according to the densities of the materials, as stated in the Paper. The question of hand-picking *versus* washing seemed to him to be not so much one of the quantity of shale present in the coal, as the size of the pieces. If the pieces were large, then he thought handpicking might be with advantage adopted, but if they were small then separation by water was that generally practised, and seemed to him the best, for it would be out of the question to extract by handpicking the thousands of small pieces of shale often found in a ton of coal. If only the larger pieces of shale could be hand-picked with economy, then separation by sizing or screening should precede handpicking, and the whole of the coal should not be passed before the operators. Sulphur could not be eliminated by handpicking, unless it was associated with the coal in lumps, but by extended crushing and subsequent washing in felspar-machines it might be reduced considerably. Whether the reduction could be effected cheaply enough to warrant the adoption of a process of washing in the case of gasworks was a question on which he would not advance an opinion. With regard to the chemical analysis furnished by Mr. Rogerson, he thought the usual method of stating returns adopted in this instance was correct even from a commercial point of view.

It had occurred to him that the drying of the coal after washing deserved more attention than had been given to it in the Paper. It was a matter of importance, especially when the coal was used

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for coking. The quantity of coke made in a given time, as well as the quality, depended to a considerable extent upon the dryness of the coal used. If much water was charged into the ovens with the coal it cooled them, and prevented the process of coking proceeding with sufficient rapidity, and the cooling effect had no doubt a deteriorating influence on the ovens themselves. It had been mentioned that at Ebbw Vale the coal from the machine was discharged on to a long fixed screen, through which the water drained, and it was then stocked in a large bunker, which allowed it to dry still more. Mr. Coppée, in the case of coarse coal, caused the coal and water, as they were discharged from the machine, to pass over a reciprocating screen, which freed the coal, to a great extent, from water; but in order to attain a better result, he raised the coal into large bunkers, in which it remained for a considerable time. In these arrangements the water was allowed to drain away through screens from the coal; but in the case of Mr. Sheppard's machine, the coal was scooped out of the water by an elevator with perforated buckets, allowing most of the water to remain in the machine. At Dowlais, the coal, after being discharged from the machine into a bunker, was stocked on a large floor covered with plates for about twenty-four hours, when the water was almost completely drained away. Mr. Coppée in the case of fine coal directed the water, with the coal in suspension, into a large tank, in which was placed the bottom of an elevator, and along the bottom of which a creeper worked, conveying the coal to the elevator as it deposited. The tank was made large, and the elevator was driven slowly, so that the water would be but little disturbed, and thus the depositing of coal was facilitated. Although the elevator and the creepers worked in water by this arrangement, and would be subject to considerable wear, still, when well carried out, this system for small coal effected a saving by reducing manual labour, in emptying settling ponds, to a minimum. In connection with some machines erected at Barnsley by Mr. Sheppard, there was a centrifugal drying machine, which received the coal after it had been well drained of the running water by passing down a long shoot or trough, with a perforated bottom. He was informed that after leaving the centrifugal machine, the coal was so dry that it would not moisten the hand.

Mr. Harvey.

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Correspondence.

Mr. Colquhoun

Mr. JAMES COLQUHOUN remarked that the Author had given a good description of the various modes of coal-washing. Before any particular system was adopted in any district, the nature of the coal and shale ought to be thoroughly examined, and the abundance, or otherwise, of water ascertained. This would enable a decision to be come to, as to whether the cheaper trough-washing plant, or the more expensive machinery-plant should be erected. The Author stated that the chief objection to the trough-washing machine was, that fair results depended upon the care taken by the persons employed; but care was necessary whether the coal was washed in the trough or by the machine system, and he had seen considerable waste in the washing done by machinery. No doubt some of the machines described in the Paper did their work very well; but it came to be an important question, whether it would not be better, in many cases, when everything was favourable, to adopt the less expensive plant connected with the trough-washing machine, and thus save the constant charges for interest and depreciation upon the large amount necessary to be expended on machine-washing plant. There was no difficulty in obtaining good results from this, and it was a simple matter to protect the workpeople from the weather. The machines at Tredegar had been working for some years, and few stoppages had occurred during all that time. In the trough-washing there was no necessity for making a separation of the different sizes of coal. It was very important to crush the coal after washing, as it improved the yield in the ovens, and made a harder coke. The ordinary crushing-rollers did their work well. Carr's Disintegrator had not found much favour in South Wales. When some of the coking coals were pulverized they contained a quantity of fine dust, and when wet there was a danger of the crusher becoming clogged. In the trough system the cost of washing, including all labour and delivering coal into ovens, was about 2*d.* per ton, and it was doubtful whether in the best machines it could be done for this sum.

Mr. Guinotte

Mr. L. GUINOTTE, Managing Director of the Mariemont, l'Olive, and Chaud-Buisson collieries, contributed a drawing and description of the screens invented by Mr. Alphonse Briart, and to which allusion had been made in the Paper (*ante*, p. 119).

Wishing to avoid the loss of time necessitated by the spreading out of the bars of the screen, Messrs. Guinotte and Briart had sought a remedy in some device which should allow of a practically

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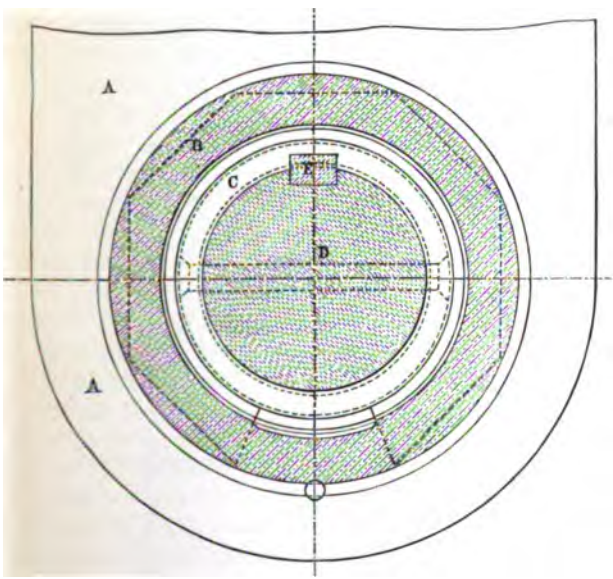
instantaneous enlargement of the apertures to any extent. This had been effected by a very simple disposition, to which had been given the name of differential grid (*entretoises variables*), shown in Figs. 6 and 7, where A A represented the bars which it was desired to open out. These bars were carried by spindles B, threaded with right- and left-hand screws, which took the sleeves C, having threads in a contrary direction. These sleeves were traversed by a shaft D, common to the whole system, and holding the sleeves by the key E; consequently the rotation of the shaft D widened or narrowed the spacing of the bars as was desired. This was effected simply by means of a handle fitted to the square end of

Mr. Guinotte.

FIG. 6.



the shaft. The degree of widening was indicated by figures on the shaft D, which served as a scale. It might also be shown on a dial-plate by a needle attached to the shaft. In order to effect the symmetrical divergence of the bars, the middle sleeve of one of the systems was keyed to the shaft, while the bars of the other system were attached to cross-bars immovably fixed to the framework of the apparatus. This arrangement, which had been adopted in all their new machines for the last three years, gave entire satisfaction. Not only was the loss of time referred to avoided, but any degree of sizing could be obtained by the same machine within the

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Mr. Guinotte.

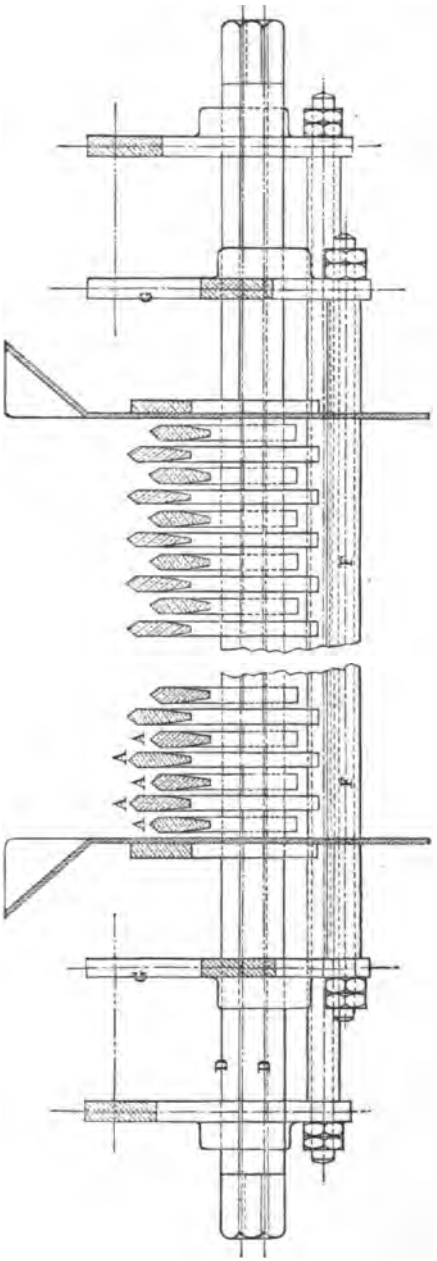

FIG. 7.

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limits of traverse of the bars, and without any expense, the cost of manœuvring the machine being insignificant. Mr. Guinotte.

Mr. J. B. Marsaut thought the different sorts of coal-washing machines embodied a limited number of principles common to all, and which had to be considered when judging of the intrinsic merits of individual machines. The Author had called attention to the fact that mechanical separation might be effected either by a stream of water ascending through the charge, or by the free descent of the material through still water. These two modes achieved the relative motion of water and of coal, which formed the basis of all the systems. But the Author had attributed to the downward movement of water an effect which it did not produce. Substances always fell through water, whether the water ascended or descended, because their density was greater. The only effect of a descending current was to quicken the process of descent, without in any way affecting the work of separation. It did not neutralise the effect of the ascending current. Further, the descending current, instead of being injurious, was very beneficial. In Mr. Marsaut's opinion, it constituted the most valuable means of preparing certain coals containing much admixture of impurities. It was this downward current that, with certain coals, reduced the yield of ash to from 2 to 4 per cent. For example a piston-jigger, having a valve to prevent the descent of the water with the charge, would under certain conditions leave from 3 to 4 per cent. more ash in coal subjected to the same number of piston-strokes than would be the case with a similar jigger without the valve. That was what he found at Bessèges, and at the moment he was constructing machines founded specially on the principle of the recoil of the water, which was jealously conserved, in order to utilise this effect. The merits of the machines of Lührig and of Coppée rested entirely on this alternate upward and downward movement, but especially on the motion of descent. There were two principal types of washing-machines; the piston-jigger, with alternate motion of the water, and the basket-washer, or English jigger; both being dependent on the relative movement of the water and of the material to be washed. Apparatus based on the alternate movement of coal and of water, realised what he had called the suction-phenomenon, which was extremely useful in respect of the degree of cleansing. It certainly augmented the loss, but this was not sufficient to counterbalance the superior amount of cleansing. These machines were the nearest to perfection. In continuous-current apparatus, which altogether prevented the return of the water with the charge, Mr. Marsaut.

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Mr. Marsaut. and which were furnished with overflows, the only effect obtained was that of sorting by equivalence. The loss was diminished, but there remained in the washed product all the impurities of duff and slack. In apparatus which only partially prevented the return of the water with the charge, and which might be called "mixed," intermediate results were obtained. Such machines were those of Bérard and of Sheppard, which latter was only an intelligent modification of Bérard's. By abolishing in Sheppard's washer the valve in the passage G (Fig. 5), a very useful effect had been produced from the point of view of cleansing. This machine thus came under the denomination "mixed" before-mentioned. In all machines working by a stream of water, either continuous or alternate, the relative movement of coal and of water remained uniform for every particle of material. This constituted classification by equivalence, which was at the same time greatly improved by the effect of suction in the return-current apparatus. On the other hand, the washers based on a free descent of the material in still water, realised the "differential relative movement." At the beginning of the descent, advantage was taken of the action of gravity, which was independent of the size of the pieces. This was known as the initial stage of the descent. It favoured classification by density, and if it could be managed so as to constitute the entire process, it would effect perfect separation of all the particles of all sizes, that was to say, without any preliminary sorting.

The distinction between the two classes of washers was capable of easy mathematical demonstration. The equation for the movement of a particle in still water was given as follows in Callon's "Cours de l'Ecole des Mines," Paris, vol. iii., p. 46:—

$$\frac{K a^3 D}{g} j = K a^3 D - K a^3 \delta - K_1 a^2 u^2 \delta,$$

where u = the velocity, and j the acceleration of the particle; a^2 the maximum horizontal section of the particle, and consequently $K a^3$ its volume; D and δ the respective densities of the particle and of water. If the water were influenced by any given vertical movement this equation held good; but for the absolute velocity u of the grain it was necessary to substitute its velocity with respect to the water, equal to the sum or the difference respectively of the velocity u of the particle and of the velocity v of the grain.

$$\frac{K a^3 D}{g} j = K a^3 D - K a^3 \delta - K_1 a^2 (u \pm v)^2 \delta.$$

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In order that there should be in the movement of the particle a period favourable for classification by density, it would be necessary that at a given moment the last term of the equation should be taken as equal to nothing. Mr. Marsaut.

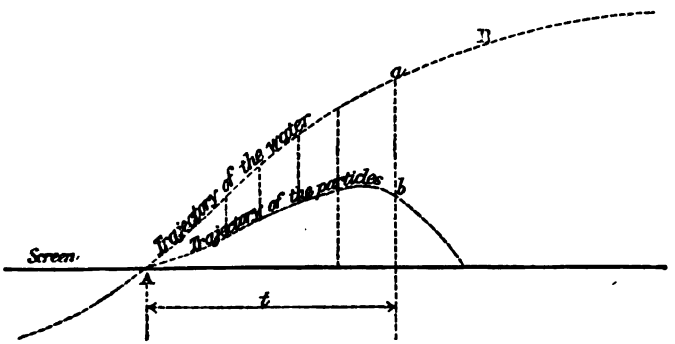
In this way the simplified equation became

$$j = g\left(1 - \frac{\delta}{D}\right),$$

and it would be clearly seen that, under these circumstances, the acceleration of the particle increased as its density, and as its density alone.

This occurred when a particle fell into still water at the beginning of its fall, so that its velocity might be neglected; there was then, at the same time $u = 0$ and $v = 0$. But practically this condition of $u = \pm v$ was never realised in machines having a current of water, as could readily be shown by the diagram (Fig. 8).

FIG. 8.



In effect, if the molecule of water and the particle first in contact left their trace on the drum of General Morin's well-known machine, the trajectory of the water would be a curve similar to A B, more or less approaching a sinusoid. The point A, where the screen had been shown, was that where the water had just the velocity-limit of the particle in water, and where consequently the water began to raise it. The particle rose in proportion to the velocity of the water, then stopped and retrograded as that velocity diminished. Hence it was evident that during the whole evolution the particle of coal had continuously descended with respect to the particle of water, developing ordinates comprised between the two curves, such as $a\,b$, representing the path traversed. Without an instantaneous stoppage of the water, impossible to produce in

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Mr. Marsaut. practice, the relative velocity $u \pm v$ could not be destroyed, nor, consequently, give rise to a distinct period of classification by density. On the contrary, in the case of free-fall descent, it was clear that at the beginning of every fall there always was a time when $u = 0$ and $v = 0$, thus producing the favourable initial period. But in free-fall washers the principle of suction would not come into play; hence a capital disadvantage resulted when treating coal mixed with impure dust.

He had stated that the washers of Lührig and of Coppée, which were nothing more than the old Hartz riddle, took advantage of suction, and even utilised it for the total separation of all the impurities. This kind of washer was at the present time in great favour in France and in Germany. It remained to be proved that it washed better than the ordinary piston-jigger with return-current. It had the serious disadvantage of requiring a considerable stream of water, which acted injuriously in the process of cleansing. Particles of $\frac{1}{2}$ a millimetre, and even larger, were carried off by this quick current, and without being sufficiently cleansed. The favour actually enjoyed by this washer appeared to Mr. Marsaut to belong rightfully to the general disposition of the apparatus, and to the water-carriage of the product, which lessened the amount of manual labour, replacing it by a mechanical power, of which the cost might be neglected.

To sum up:—

1. The return-water piston-jigger effected the cleansing in a superior manner. It even dispensed with preliminary sizing, but it entailed more waste.

2. The same type of jigger, with a valve to prevent the return of the water, lessened the waste, but did not cleanse so effectually.

3. Free-fall washers gave results equal to No. 2 type, if this coal were first sized, a result which was, moreover, increased by the effect of the initial period of the fall.

4. Free-fall washers left nothing to be desired for coals well-sorted as to size, as in the case of all the other types of washers not returning the water with the charge.

The initial period of fall and suction constituted the two elements of difference between all systems of washing by water; accordingly, as either of these elements preponderated, so would the washing be more efficient in the different types. Unfortunately, suction entailed a slight waste of useful material, but that was far from counterbalancing all its advantages. By well considering these theoretical principles it was quite possible to arrive at a correct valuation of the different forms of washer. The other

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part, viz., the machinery, had to be considered as between manual and mechanical methods. Both had their peculiar advantages, and, consequently, their advocates. It must also be remarked that the special conditions of each case and the results aimed at went for much, and would probably influence the sort of machine chosen. Mr. Marsaut.

Mr. HARVEY had pointed out in the Paper, that if a piece of light coal and a piece of heavy shale of the same form were exposed to the action of the same current of water, the velocity communicated to the coal by the force of that current would be greater than the velocity communicated to the shale. Mr. Marsaut admitted the truth of this statement with regard to the upward current, but seemed to deny the same effect to the downward current, as he stated that "the only effect of a descending current was to quicken the process of descent, without in any way affecting the work of separation." Mr. Harvey.

To determine what effect the downward current had on the particles of coal and of shale, let the motion communicated by gravity be neglected, as that would not be influenced by the force of the current, but would be the same in a machine in which there was no downward current as in one with downward current. The force exerted by a current against a solid was given by Rankine[1] as—

$$F = k\, s\, A\, \frac{v^2}{2g}$$

In this expression A = area of greatest cross-section of the solid, s its density, k a coefficient depending on the form of the solid and which for a cube = 1·477. Taking a machine without overflow (the return-water piston-jigger class), having a bash 5 feet long, piston 2 feet long, both being the same width, and let the piston make thirty double strokes of 1 foot long per minute; the velocity of the current up, or down, through the bash would be $\frac{30 \times 2 \times 2}{5} = 24$ feet per minute, or 0·4 foot per second. Assuming that the pieces of coal and of shale were 1-inch cubes, the force of the current on each would be—

$$F = 1{\cdot}477 \times 62{\cdot}425 \times \frac{1}{144} \times \frac{0{\cdot}4^2}{64{\cdot}34} = 0{\cdot}0016 \text{ lb.}$$

The weight of a cubic inch of coal with specific gravity of 1·26 = 0·045. The weight of a cubic inch of shale of specific

[1] "Applied Mechanics," p. 598.

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Mr. Harvey. gravity 3·0 = 0·108. The force exerted by the current on the shale would be the same as that exerted on the coal, viz., 0·0016, and would be sufficient to communicate to the mass of matter in the coal a velocity of

$$\frac{0{\cdot}0016 \times 32{\cdot}17}{0{\cdot}045} = 1{\cdot}14 \text{ foot in one second;}$$

whereas the velocity which the same force would communicate to the mass of the shale

$$= \frac{0{\cdot}0016 \times 32{\cdot}17}{0{\cdot}108} = 0{\cdot}47 \text{ foot per second.}$$

The tendency of the force was, therefore, to separate them, as well as to accelerate their descent; but instead of conducing to bring the heavier shale below the coal as the upward current did, and as also did the force of gravity in still water, the tendency of the force of this downward current was to bring the lighter coal below the shale, and thus to some extent it neutralised the effect both of the upward current and that of gravity, and as a consequence it involved waste.

He could not agree with Mr. Marsaut's statement that the merit of Mr. Coppée's machines rested "especially on the motion of descent." Mr. Coppée, in his machines for washing coarse coal, used the slot-bar motion referred to in the Paper. This had the effect of causing the upward stroke of the piston to be performed more slowly than the downward stroke, and thus reduced the velocity of the return current. Moreover he admitted the water into the machine under the piston with a head of several feet, and he laid so much stress on the uniformity of head, that he preferred supplying the water by a centrifugal pump, driven at a given velocity, to drawing the supply from a reservoir with the risk of a variable head. With Mr. Marsaut the Author considered Coppée's coal-washing establishments well arranged, but he did not think the favour they enjoyed depended to any appreciable extent on the adoption of water as a means of transport; for this means of transport he used but little in the case of coarse coal.

Coal-washing without previous sizing appeared to the Author to be established on no very rational basis, and could probably be effected as efficiently, and perhaps more so, in a machine with a strong return-current, as in a machine in which that current was prevented. But his observations led him to favour preliminary sizing, and then separation according to density in an intermittent upward current of water. He had known establishments where

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sizing was carefully effected, and where separation was afterwards performed in an upward current at which 12 per cent. of ash was removed, and the washed product was only 17 per cent. less in weight than the unwashed coal. On the other hand, he had seen at a Bérard machine, where no means were used to prevent downward current, and where no sizing was done, a loss of 20 per cent. by weight sustained by the removal of only 6 per cent. of ash. Mr. Harvey.

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16 May, 1882.

Sir F. J. BRAMWELL, F.R.S., Vice-President, in the Chair.

(*Paper No. 1879.*)

"On the Various Systems of Grinding Wheat, and on the Machines used in Corn-Mills."[1]

By WILLIAM PROCTOR BAKER.

IT is impossible within the limits of a short Paper to discuss exhaustively the processes, and fully to describe and criticise in principle or detail the machines used in modern corn-mills; such a discussion could be compassed only in a volume of considerable dimensions. All that will be attempted in this Paper is a statement of the conditions under which the miller's business has to be carried on in the United Kingdom, as compared with those countries from which flour is largely imported, followed by a general sketch of the prominent features of the processes in use, and of the machines employed. Except in one or two cases, mention or description of particular machines will be avoided, and the aim will be to enumerate the elements which are common to the design, or the objects which are sought to be attained by classes of machines. There would have been space perhaps to describe, with the aid of drawings, one typical machine in each class; but when in almost every case there are machines of merit competing in the market, it appeared that in selecting one, injustice may be done to the inventors and makers of those not named. There is no machine in use of which detailed accounts have not been published in the milling or engineering periodicals, which are easily accessible; so that, as any drawings to accompany this Paper would not be in illustration of novelties, they have been omitted.

Although there is abundance of materials whence to construct a history of the art of corn-milling from early periods, yet it is not

[1] The discussion upon this Paper was taken together with that upon the two following ones.

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expedient to attempt to give a description of all the various systems, nor of all the machinery of which records exist. A rapid glance may however be taken of the modes used by the ancients to obtain flour from wheat. The earliest known implements in use were the pestle and mortar, in which the grain was pounded by hand, and rollers, between which and a hard stone tablet the grain was crushed by hand-pressure. The Eastern hand-mill, still to be seen, is the first recorded instance of the grinding operation by millstones on the same principle as is now practised. At the commencement of the Christian era these had been developed into the form to be seen among the remains at Pompeii; the lower millstone was fixed, and, among the Romans, the grinding surfaces were sometimes conical, sometimes spherical, sometimes flat; the upper, or moving stone, was turned in one direction by a lever attached to its periphery, first by hand, then by animals, afterwards by water-power; the notable improvement over the pestle and mortar, or rolling process, being that the corn to be ground was distributed between the grinding surfaces through a hole made for the purpose at the centre of the upper and revolving stone; and as the meal, *i.e.*, the ground corn, escaped from between the grinding surfaces at the edges of the two stones, a continuous stream of corn could be passed between the stones, and the operation could be carried on so long as the upper stone was caused to revolve. After the grain had been thus crushed or ground, the fine particles of flour were separated from the imperfectly ground fragments by hand-sieves, formed of pierced skins or parchment. The partly-ground fragments of wheat were again and again passed between the millstones, until as much flour as practicable had been extracted. The residuum was the skin of the wheat, called "bran." These millstones and sieves are the germs from which have been gradually developed the elaborate machinery of the modern corn-mill. Coming down to a thousand years ago, the millstone then in use was probably of the same type as the millstone of the present day. The features which are identical between the two periods are these: the lower, or bed-stone, fixed; the upper stone, or runner, made to revolve by power; the grinding surfaces horizontal and nearly parallel to each other; the runner fixed to, or hung loosely on the top of a vertical spindle passing through the centre of the bedstone; the foot of the spindle carried on a bearing so contrived that it may be raised or lowered at the wish of the operator, while the spindle is in motion for the purpose of increasing or diminishing the distance between the grinding surfaces of the two millstones; means of regulating the volume of the stream, or

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"feed," of corn, and its even distribution between the grinding surfaces; the establishment of a sufficient speed of rotation to throw out the ground material; the enclosure of the millstones in a tub or case; and the delivery of the meal from it by a pipe. The method of sifting the meal after it was ground by hand-sieves seems to have been the only one used down to recent times, but the material for covering the sieves varied among different nations; thus the Egyptians used rushes and papyrus; while it is recorded that pieced skins and parchment, horsehair and linen, were employed in the first century of the Christian era. Among the Romans the grinding, sifting, and baking operations were all conducted in one house. In London, however, in the fourteenth century, it is clear from the regulations to be found in the "Liber Albus," that the miller had a separate establishment from the baker; that the miller ground the corn to meal; that the meal was delivered to the baker, who sifted it by sieves or bolts at the bakery, and the master-baker was bound to instruct his men twice a year in the mode of bolting. In Shakespeare's time the word "bolting," as applied to the sifting of meal, was familiar, but whether there was any machine used for the purpose besides the hand-sieve does not appear. Flour-dressing machines, as those machines are called which perform sifting operations, may therefore be considered the product of comparatively modern times, though it is curious to observe that Americans name all such machines "bolts."

Attention has been lately called in many ways, and especially by the Exhibition of Mill Machinery last year, to the revolution that has been taking place in the art of milling, and it has been erroneously supposed that, first the Hungarians, and afterwards the Americans, had, by some imaginary secret processes, been able to eclipse the corn-millers of all other nations. It may be well to state here that there are no such secret processes, but that the Hungarians have produced flours still unsurpassed in excellence by skilful manipulation of their native wheats (which, though yielding very bad flour when ground by old methods, possess admirable qualities), and that the Americans, by recently adopting similar, but not identical processes, modified to suit their native wheats, have been able to make flours second only to the Hungarian in quality; and it should be understood that out of similar materials, millers in England could, by using similar machinery, attain the same results. As however the Hungarian and American mills buy up all the special qualities of wheat from which the finest flours are made, these materials are not obtainable by the English flour

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makers: and it should also be understood that the conditions of the trade are very different in England to those of either of these other countries; for in England the millers work chiefly for the supply of the district near their mills, and each mill must be adapted to produce the particular sort of flour consumed in that district; and in some districts the taste is entirely for fine white bread, in others for medium, and in others for low brown bread. As a rule the demand in each district runs on only one class of flour, and the local miller is obliged to manufacture that sort to meet the local demand.

The processes used in Hungary are based on the principle of dividing the flour produced from the same wheat into eight or ten or twelve different qualities. The fine qualities, which command very high prices, find their market in various central and western parts of Europe, and in certain parts of the United Kingdom, and in Brazil, while the medium and lower qualities find a local consumption as well as a demand throughout the south-east parts of Europe.

In America, the recently-adopted practice is to divide the flour made from one sort of wheat into several grades of quality, fewer however than in the Hungarian method, for which in like manner a sale has to be found in various and perhaps widely-separated markets.

There is never any difficulty in selling flour of the medium grades, which is the flour almost universally in demand; but for flour of the finest quality and highest price the demand is restricted, and flour of the lower grades is at times only to be disposed of at comparatively very low prices, although all the markets of the world may be open to the miller who knows the quality in demand in every district and can send appropriate flour to each. Now the English miller must manufacture for local demand; for, having already incurred the cost of freight and carriage on the wheat in bringing it to his mill (wheat which he may have to buy in competition with his foreign competitor), he cannot afford to pay another freight on the flour to carry it to a distant place of consumption where he will meet again the competition of the Hungarian or American miller, who can send flour direct to the same place and thus incur only one freight on it (and that freight less than the wheat freight). Thus it is that every miller in England must work for local demand, and must seek to adopt a system that will produce the quality of flour required by the taste of his own district, and he cannot, like the American or Hungarian, depend on finding an outlet

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for his manufacture in distant markets. This is the reason that American and Hungarian systems have not been extensively adopted in this country. Great caution is required not to be deluded by the temptation to manufacture a superior quality of flour without the assurance that it can be sold (if it can be sold at all) at a superior price; and in forgetfulness that the making of the superior flour entails also the production of a quantity of inferior flour that will be a drug in the local or any market within reach. And the millowner in England has another difficulty to contend with. It may be roughly calculated that two-thirds of the wheat henceforth to be ground in England will be of foreign growth. Foreign wheats differ materially from each other and from home-grown wheats in character, and in the quality of flour produced from them; but the miller is obliged, as has been stated, to work to the standards of quality of flour of his district whatever they may be; that is to say, that he must produce, whatever may be his materials, a certain fixed quality of flour. The supplies of English wheat differ in quality in each district from year to year in sympathy with the variations of the weather: foreign wheats from the same district change less than do the English from year to year; but the foreign wheat available to the miller not only varies in quality from year to year, but the supply also varies in different parts of the same year, according as each country sends forward its produce; thus it may be that at one time American spring wheat may predominate; at another, American winter wheat; at another, Californian, Oregon or Chili wheats may fill our stores; at another, Russian; and so on, Indian, Australian, German, French, each in its turn, and each differing from all the rest in character. As all these wheats require different treatment in grinding to produce the same character and quality of flour, the English miller, therefore, having to produce constant qualities of flour, requires to be equipped with such apparatus as will enable him to deal equally well with all these differing materials, for to conduct his business profitably he must be able to work up whatever may happen to be in proportion to its quality the cheapest wheat of the day. He must adopt a system applicable to all sorts of wheat, and not one that is profitable only when employed on only one description, such as some of the foreign systems are. On the other hand, his foreign competitor has no such difficulty. He draws his supplies from the districts immediately surrounding his mill; they vary only from year to year according to the harvest, and there is no wide difference in the character of the grain between one year

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and another, and the quality is the same from day to day throughout the year; so that his task is only to select the best method of dealing with one particular sort of wheat, and of that wheat to obtain the produce in the form that will fetch most money without regard to the wants of the population at his door, for he has all the accessible markets of the world open to him. The most profitable system of flour-making is that which causes wheat to yield the largest proportion of high quality fine flour, provided always that a sufficiently high price can be realised for it. But it is not difficult to overdo the market with fine flours, that is, to produce more than the demand will take off at sufficiently high prices; and this is what has happened: first to the Hungarians, who are unable now to keep their mills profitably employed because their flour was displaced to a great extent by the Americans, whose materials were cheaper; and then to the Americans, for, attracted by the profitable nature of the business, they have erected mills on a very large scale depending on finding an outlet for any quantity of the finest flour, and it soon happened that the shipping ports were glutted with these fine sorts for which adequate prices could not be obtained, while there was not enough of medium qualities to meet the demand. With these warnings it is additionally important that English millers should be cautious only to adopt such systems as will enable them to make profitably those particular qualities of flour for which a demand exists in the district supplied by each mill, and that engineers should, in designing mills, carefully adapt the machinery to be supplied for that purpose. A mill suitable for Glasgow, where fine flours are largely consumed, would not be suitable for London, where the bulk of the demand is for medium grades. Each district has its own peculiarities, and one universal type of mill will not succeed everywhere, either with regard to the qualities of flour it is calculated to produce, or with regard to the raw material that may be available. The selection of a system and of the machinery must be matter for the judgment of the millowner, who alone can know the requirements of his trade as to qualities of flour, and what are likely to be the sorts of wheat which he will have to operate upon; and he should turn a deaf ear to the blandishments of the mill-furnishers who promise that marvellous profits shall arise if only the special system they have an interest in advocating be adopted, whatever may be the commercial situation of the mill.

It will be useful to define more particularly what has to be accomplished in wheat-grinding, and then to discuss generally the

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various systems in practice. The shape of the wheat-corn is familiar, and it is well known that, physically, it consists of the germ, the flour-yielding body of the corn, and the skin or hull which encloses it. The flour-yielding body is built up of minute cells of irregular and many-sided shapes, containing the starch and gluten of which flour consists. The hull or skin is closely attached to the cells next it, and it cannot be stripped off like the skin of a nut or the hull of an oat. The problem for the miller is how, in the simplest, cheapest, and most complete manner, to separate the germ and skins of the wheat-corn from the flour; and, further, as the quality of the flour varies according to its position in the wheat-corn, how to separate the richest and best of the flour-containing cells from those that are inferior. In consequence of the adhesion of the skin of the wheat to the interior it is not possible in practice to make an absolutely perfect separation of the parts; so that his aim must be to obtain from a given weight of wheat the greatest quantity of the best quality flour the wheat will practically yield, and the least quantity of "offal," as the skins and germ are technically named.

It should be observed that the value of offal in the market is very little enhanced by leaving flour in it; while the value of flour is much diminished by the slightest admixture of offal or "bran." The financial importance of the complete separation of the flour from the offal is obvious from the consideration that, while flour varies (at present prices) from 10*s.* to 23*s.* per cwt., offals are worth only from 4*s.* to 6*s.* per cwt. The most important point is therefore not to permit any particles of bran to be mixed with the flour, because such a mixture seriously reduces the value of the flour; and, that point secured, then to be careful that no loss is made by leaving valuable flour among the offal to be sold at the very low comparative price which it fetches.

Up to within about ten years ago the general system in this country and in America was what is termed low grinding. It is assumed that the form and arrangement of millstones is well known, and low grinding means that the grinding surfaces of the two stones are brought so closely together as to crush at one operation all the interior of the grain into the powder known as flour, while the exterior skin is spread out into flat flakes (called bran), off which all the floury particles have to be scraped. The skilful operator under this system so managed the arrangement of the stones that while he achieved the object of cleaning the bran, yet he avoided as much as possible the breakage of the skin for two reasons—(1) because the less broken it is, the less are the particles

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likely to pass with the flour through the sifting material; and (2) because in commerce the larger the flakes, the more valuable is the bran. It is indeed possible by very well-arranged millstones to perform the grinding so completely that the miller has no more to do than to divide the flour from the offal by sifting, or dressing the meal, as the millers' term is. This is the most simple form of grinding, and, even with all the latest improvements, is that which is best adapted to the requirements of those localities where the wheat used has a somewhat tough skin, and where at the same time the demand runs on a medium or somewhat low class of flour. Wheat, however, varies very much in the toughness of the skin, and while the skin of some wheats is very difficult to break, in the case of other sorts the skin is as brittle and friable as the interior of the corn. Conspicuously this is the characteristic of the wheats produced in Hungary and in the North-Western States of America, and rich as these wheats are in all the elements which go to make good flour, their skin is so brittle that any attempt to grind the interior parts into flour by low grinding has the inevitable result of breaking up the skin at the same time, and thus producing a flour in which there is a large mixture of minute particles of bran, and therefore flour of very low quality. These particles of bran have the effect not only of colouring the bread by the admixture of so many specks, but produce also a certain secondary fermentation, which destroys some of the constituents of the flour and discolours the whole of the bread. The Hungarians, finding it impossible to keep the skin unbroken, and the kernel of their wheats when exposed to the action of the millstone, on account of their structure and brittleness, having a tendency to break into small fragments, rather than into flour, like soft wheats, availed themselves of this circumstance, and instead of seeking to make flour at one grinding operation, they regulated their millstones so as just to crack or break up the wheat into small gritty particles, named by the Germans "gries," by the French "gruaux," and in the United Kingdom "semolina." The breaking operation had to be repeated several times, and the semolina obtained by the successive breaks, mixed as it was with small particles of bran, was exposed to winnowing operations, which got rid of the bran and left the small cellular fragments of the interior of the wheat in a pure state, free from bran. The pure semolina could then be crushed down by millstones into fine flour. Similar principles have been applied to the treatment of the hard wheats of the North-Western States of America, with some modification of the process. Between the low grinding, which is the most simple, and

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the Hungarian system, which is the most elaborate in detail, various systems have been developed, and are known as high grinding, half-high grinding, new process, and gradual reduction, and modern machinery has been contrived to achieve some special object in connection with one or other of these processes.

Whatever may be the subsequent treatment of the meal, the mode of grinding the wheat is what gives name and character to the process, and it is necessary now to give a brief sketch of the leading systems.

In low grinding the surfaces of the millstones are kept sharp by being dressed by a mill chisel. The working surface of a millstone after running a few days becomes smooth and polished, and it will then no longer scrape the floury particles off the bran; and the dress takes place by making cracks or cuts with a mill chisel, varying in width and depth according to the quality of the millstone and the style of grinding; these cracks are made parallel to each other, and vary in number from twelve to twenty-five per inch. The man who performs the work is called a stonesman, and he is paid at a higher rate than workmen in any other department of the mill, as the success or failure of the grinding operation depends upon his skill and judgment in dressing the stone. The furrows are the channels made in the stone, and the edges and surfaces of these have to be kept sharp and true in the same way as the plane surfaces of the stone. In grinding, the surfaces of the stones wear away unequally, and one of the chief duties of the stonesman is to keep the surfaces perfectly true, by cutting off any hard and high spots, and by dressing very lightly or scarcely touching any hollow places. As the surfaces of the stones approach each other in this system very nearly, when running, it is obviously of the greatest importance that they should be true. The object is to clean the bran at one operation, and to break it as little as possible, for the less it is broken, the less likely are there to be minute particles of it which would pass with the flour through the meshes of the sifting apparatus, and thus become inextricably mixed up with the flour. By this system, although it is not possible to avoid making any gritty particles (called middlings), yet nearly the whole of the interior of the corn is reduced to fine flour at one grinding, and nothing remains but to dress (that is, to sift) the meal and divide it into flour and the different sorts of offal, when the operation is complete. It is the most simple system, and the least expensive in installation and working, and requires the least space. And it is more than doubtful whether the results obtained by it from wheats, such as our native English wheat, in a

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district where flour of moderate quality is desired, can be surpassed by the more elaborate procedure of systems of more recent invention, although it is the fashion to sneer at those who practise it as "non-progressive."

In high grinding the object of the operator is just the reverse of the low grinder, viz., to avoid as much as possible making flour when the wheat passes through the stones for the first time. The idea is that the corn should be rolled abroad under very little pressure from the millstone, so that while the bran is detached from the floury particles of the interior of the grain by gentle rubbing, those floury particles should be left as much as possible in the gritty condition of semolina or middlings, while the bran is to be left to the greatest extent possible unbroken, and the miller is not careful that it should be absolutely clean. It is therefore needful in this system either to regrind the bran for the purpose of cleaning it, or to leave some flour adhering to it. If the bran be re-ground, the resulting flour is always of very low quality. If flour be left adhering to the bran there is waste of flour. The desire is to make as little flour as possible, because all the flour produced at the first grinding is more or less mixed with specks of the branny coat; on the other hand, by the winnowing operation, to which the middlings are afterwards subjected, it is possible in theory, though in practice difficult, to get them purified from all these specks, and the middlings can then be broken down into flour by a subsequent grinding, and that flour is nearly pure, and consequently of high relative value. Instead, therefore, of keeping the surface of the millstones sharp, the high-grinding miller seeks to keep them extremely true, and then rubs them down to an even surface not actually polished, but very slightly rough. In treating the meal after this grinding, the offals are divided from the flour and the middlings, the middlings are divided from the flour; they are then purified by winnowing, and being reground and the resulting meal sifted, a very fine flour is obtained; the bran also being reground produces a very poor flour. The produce, therefore, is in the form of flour of at least three qualities, viz., the flour produced at the first grinding, the ground middlings, and the bran flours, instead of one quality as in the low grinding system; and thus high grinding can be profitably practised only when a market at a comparatively high price can be found for the fine flour. All depends on this, for it must be observed that the flour produced at the original grinding is not so good as low grinding flour from the same wheat, because it does not contain the very good flour

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made from the middlings, and that the bran flour is a very inferior article. So that the profit of this system of working depends entirely on the maker being able to dispose of his fine flour at a high price, and to find a market at not too low a price for the inferior and bran flours.

Under another system known as half-high grinding, while the bran is cleaned at one operation, middlings are produced to a larger extent than in low grinding, and being purified and re-ground, are mixed with the original flour with the effect of improving its quality, or the middlings may be sold separately at a higher price. This appears to be the plan best adopted for the greater number of mills.

Gradual reduction, however, is the system under which undoubtedly the highest quality of flour can be manufactured. The object of the operation is to break up the whole of the interior of the corn into semolina, to purify and repurify the semolina, to classify it according to its quality (for it varies in quality according to its position in the corn), and to crush it into flour of various grades. By these operations the finest known flours are made, and the profits depend on wheats of fit character being obtainable, and on sales of the finest flours at very high prices being practicable. But the demand for such flours is limited, as the Hungarians have found to their cost by the pressure of the American competition, and as the Americans discovered by having had their markets glutted with quantities of fine flour far exceeding that for which there was a demand, and by the consequent depression of the prices of such qualities below remunerative rates. It has been ascertained that the system does not pay, if all the separate qualities be mixed together to form a medium flour, for its profits depend on the relatively high prices paid for the highest quality flours: slight improvements in quality in high grades being marked by much larger increments of price than similar differences in medium sorts. Moreover, the system is not adapted for soft tender wheats, but only for such wheats as are hard and flinty in texture, brittle enough to break into fragments instead of being crushed by pressure into powder or flour. The operations are now carried out chiefly by roller-mills, and the following is the process. The wheat is led between a pair of rollers, which are fluted or grooved, running at a differential speed, and set at a distance apart slightly less than the diameter of the wheat corn; the corn is thus slightly cracked; the cracked corn is sifted to remove any dust that may have been disengaged; the cracked corn is then led to another

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set of rollers working somewhat closer together, which carry the breaking of the grain farther than the first pair; the resultant meal is again sifted, and this time fragments of the interior of the corn are obtained in the shape of gritty particles, which are accompanied by some flour; and these alternate cracking and sifting operations are again and again repeated until all the interior portion of the grain has been disengaged from the bran. The roller-mills are so arranged as to increase gradually the pressure on the corn at each successive cracking, and the grooves of the rollers are finer and sharper so as gradually to scrape all the flour-bearing particles off the bran. The great object is to avoid the production of any flour during these successive breaks, and to obtain as much as may be of the interior of the wheat in the form of gritty fragments, known as semolina or middlings. It is impossible to avoid, even with the wheats best adapted for the process, the production of a certain quantity of flour in these successive breaks, and after the separation of the bran, which generally has to be finally cleaned by millstones, a meal remains consisting of semolina of various sizes, particles of bran of corresponding sizes, and flour. As for the purpose of purifying the semolina it has to be passed through winnowing machines, and as the flour would be blown away if taken into those machines, the first step is to separate all the flour from the semolina and particles of bran by sifting. Next, as the winnowing is a very delicate and nicely adjusted operation, it is necessary to divide the semolina into gradations of size, as the amount of wind which would be fit for the larger sizes would blow away the smaller. This operation is effected by means of silk or wire cloths adapted for the purpose. The semolinas are then passed through purifiers, which remove all the branny particles that are lighter than the semolina, though they may be of the same size, and are so nicely adjustable that they are capable of separating the more dense semolina from that which is less hard and compact, and also semolina which has particles of bran attached to it from pure semolina. In this way the semolina can be purified and sorted into various qualities, and it then remains to crush them down into flour. This is accomplished by millstones, or by rollers of smooth surface working under considerable pressure. The flour obtained is sifted out of the meal, and the residue is again treated as was the original semolina, and the operation is repeated as often as may be required to obtain the whole of the flour. The flour, however, from each successive grinding becomes worse. And thus it is that from the original breaks of the wheat, from each quality of semolina, and from the

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successive grindings of semolina, various qualities of flour are obtained. As, however, has been already stated, this system can be used with financial success only with appropriate wheats, and when a market can be obtained at remunerative prices, which must be comparatively high for the fine flours. For as the process is a costly one in consequence (1) of the larger size of the building required for the various and complex machinery employed; (2) of the cost of the extra machinery; (3) the cost of extra labour and skilled and expensive superintendence required to conduct the elaborate details of the operations, it cannot compete in point of the cost of manufacture of the ordinary grades of flour with either the low grinding or half-high grinding systems, as those are much more economical processes to conduct.

The delicacy and the exactitude, and even the intricacy, of all the separate processes of the gradual reduction system, as compared with the simple proceedings in the low grinding system, no doubt give the former a greater charm for the scientific and mechanical mind, but the cheapness and ready adaptabilty of the latter to working nearly all descriptions of wheat will give it a vitality not perhaps expected by the advocates of progress, and it may safely be predicted that no time can be assigned when the sound of the millstone shall be heard no more.

A sketch of the various systems of grinding having been given with a careful avoidance of technical details, it remains to attempt a general survey of the great variety of machines now used in carrying out the processes that have been briefly described. Many machines, constructed on the same principles and intended to accomplish the same duties, differ only slightly in matters of detail, but the difference, although apparently minute, is often sufficient to distinguish a successful from an unsuccessful machine.

It is proposed to describe the general features only of classes of machines, as it is impossible to deal with the merits and defects of individual machines in the space available. The machinery in use may be classified according to the work to which it is applied, and the classes would, corresponding to the rotation of the processes, be thus divided:

1. Wheat cleaning and separating.
2. Grinding.
3. Sifting or dressing.
4. Semolina or middlings purifying.

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1. Wheat cleaning and separating.

The wheat of commerce as delivered to the corn miller is not in a fit state for grinding, because even when the grower is provided with threshing and winnowing machinery of the best agricultural type, and uses it in the most careful manner, he is unable to deliver the grain free from admixture of dust, chaff, or seeds; and there is a gradation in the amount of matters other than grain, found amongst the wheat from that proportion which is contained in the carefully cleaned corn, down to that which exists in corn brought from foreign countries where the peasantry are unskilled in the use of machinery. Besides the foreign matters delivered with the wheat by the farmer, there is also to be found in imported wheats pieces of wood, sticks, rope, twine, matting, nails, and a variety of articles, which are introduced during the conveyance of the wheat, either in carts, barges, ships, or railways. In wheat from some countries stones are always to be found mixed with the grain. It is therefore evident that very complete arrangements for getting rid of all these impurities is the first necessity in every mill.

It is desirable in well-managed processes of cleaning to begin by getting rid of all easily separable matters, such as dust, and other matters that are larger than the wheat corns, and those that are smaller. Such things are readily removed by oscillating or rotating sieves, covered with wire gauze or punched metal plates, with meshes or holes that at one part of the machine let the wheat through and throw out the larger articles, and at another part let all the small things through and retain the wheat. There still remain, however, chaff, shrivelled grains, husks of grains, the interior of which has been eaten by weevils, and bits of straw and chaff. In order to remove these the corn is caused to fall in a stream through a current of wind, the intensity of which can be regulated by valves, and all these light particles are blown, or by preference sucked, away. There remain, however, mixed with the wheat other matters, such as stones, particles of iron, and seeds of the same weight as the wheat, but round instead of oblong, and oats, which are much longer than the wheat. For the removal of each of these where present a distinct machine is required, and efficient machines leaving nothing to be desired exist for each purpose. For the removal of iron, the quantity of which mixed with wheat is large, and which has been increased by the adoption of wire-

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binding reaping machines, the wheat has to be passed in a stream over an arrangement of powerful magnets. There are some descriptions of wheat, Egyptian for instance, which contain so much mud, and the grains are so coated with dirt, that nothing short of washing thoroughly will cleanse them. Powerful machines of various types are made which accomplish this operation. The grain becomes soft in the washing process and washing necessitates drying, and the drying is partly done by centrifugal machines, but the application of heat is needed before the corn can be made sufficiently hard and dry for grinding. Kilns, or steam, or hot-air drying machines are therefore needed at this stage. The wheat, having been so far freed from extraneous matters as the machines already mentioned will permit, still has among it particles of hard mud, and there is loose dust, and dirt and dust attached to the coat or lodged in the crevices of the grains. To detach and remove this dirt, and to remove loose particles of skin and, so far as possible, the hairy end of the corn, and to break up any bits of mud, strong friction is applied, and the most approved practice is to use, not, as formerly was the case, machines with rough surfaces, but rather such as depend for their operation in rubbing the corns one against another. These machines are provided with air currents which carry away from among the mass of grain the dust as fast as it is detached. But after this process there still remains dust attached to, or lodged in, the crevices of the corns, and finally to polish the grain it is subjected to machines which, while turning it over in all directions, brush it under a slight pressure. The grain thus treated is at last ready for grinding.

Here it may be well to remark that decortication by a variety of methods has been attempted, but that on account of the irregularity of the shape of the wheat corns, and of the existence of the crease or fold from which the skin can by no means be removed, complete decortication has never been accomplished, that it is an operation which requires a large expenditure of power, and that in any case it must be accompanied with considerable waste in consequence of the breakage of the grains. So that it does not appear probable, or indeed possible, that the separation of the skin of the wheat from its kernel by decortication will ever be accomplished by mechanical means. When the skin is spoken of it must be understood that the entire skin, consisting of five layers, is intended; of these the outer skins are easily detachable, but as they are composed of woody fibre only, and have no chemical action in the bread-making process,

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their removal alone is not attended with any advantage worth the trouble and cost.

The only further operation to which wheat is subjected in some cases, where a preliminary crushing, or rather cracking, by rollers is adopted, is to size it; that is to say, to divide the small corns from the large, so that each may be separately treated.

2. Grinding.

The wheat, having thus been thoroughly cleaned, is ready for grinding, and the grinding is accomplished either by millstones, by rollers, or by disintegrators, or by a combination in successive stages of these means of reduction. Millstones are so well known, and every detail of their arrangement, so far as mechanism is concerned, has been so frequently discussed, that it is not needful to enter here upon that part of the subject. But there has been so distinct a change in the last few years with regard to the dress (which is the term used for the mode of furrowing or grooving the millstone), that it cannot be passed over in silence. In the low-grinding process little change has been made; but in all the high-grinding systems, however modified, wherever the desire has been to increase the produce of semolina, or middlings, in proportion to the produce of flour, there has been a complete reversal of the old principles of dress; for in the old plan, however the shape of the furrows may have differed, the area of the furrows was not more than one-fourth or one-third of the plane surface, or lands, of the stone; in the new practice, while the different plans are legion in number, they all agree in increasing the number and area of the furrows, leaving a very small proportionate area of lands. The number of edges of furrows thus being multiplied, and the plane areas, which are the grinding or rubbing surfaces, reduced, and the surfaces set farther apart when the stones are at work, the tendency of the action of the stones is clearly to break the grain into small fragments, rather than to crush and rub it into flour. And that occurs also which may have been expected, viz., that the bran is more broken up and is not scraped clean, as in the low-grinding system.

Roller-mills are, however, the novelty of the day, and their use has been much extended in the last two or three years. The designs and construction of these machines are most various, and each type is probably conspicuous for some advantage, as it is also for some drawback or defect. As it is impossible to describe even

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a tithe of the different varieties, and to discuss the details of them, it appears to be more useful to consider generally what are the uses of roller-mills, and what are the essential and important features in their construction.

A roller-mill, then, is destined for the breaking down or reduction of either wheat, or semolina, or middlings. But the machine that is adapted for one purpose may be by no means the best to accomplish another, and even to-day the subject has scarcely more than emerged from the experimental stage, and there has not been time since their general employment to test completely and conclusively the advantages and disadvantages attending the use of all the various forms of machines. And an expression of regret cannot be omitted that these roller-mills should be as they are, with very few exceptions, the production of foreign workshops. A very large proportion of the roller-mills at work in this country have been made in Switzerland and Hungary, and a few come from America. The introduction of the form of roller which has recently found so general an application is due to a Swiss, Mr. Wegmann; and it was in the mills at Budapest that the employment of them on an extensive scale was first made.

What is required of a roller-mill in breaking wheat is, that it should leave the bran, or skin, as far as possible intact, and that it should reduce the kernel, not immediately to flour, but to the small fragments known as semolina, and should avoid crushing any of the semolina to flour. The function of a roller-mill in treating semolina is either to crush it at once to flour or to reduce it to smaller sizes to such an extent as the operator may desire.

The first point to consider is the material from which the rollers themselves should be made. The material should be homogeneous, so as to secure the permanence of an even surface, and to avoid its wearing unevenly, either in large spaces or in small pits or grooves, or so that unworn prominences should be left; it should be sufficiently hard not to receive damage from pieces of quartz or metal (such as nails) passing between the rolls; and tough, so that the edges of the grooves cut in the surface of the rollers may not break away. It must be borne in mind that the coat of the wheat contains so much silica that the hardest materials, when in constant moving-contact with wheat, wear away. The materials employed have been cast iron, cast steel, forged steel, chilled cast iron, and porcelain; and of these, chilled cast iron and porcelain are the two which answer best. Of these two sorts the iron rollers are fitted for and used for every description of work, both as

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smooth rollers and with grooves, while the porcelain rollers do not stand the wear of breaking down wheat, nor do the edges of grooves in them stand wear; but, as smooth rollers for breaking down the softer kinds of semolina and middlings, they are by many preferred to iron on account of the porosity of the surface. Not but that it is contended (and experience confirms it) that the polished hard iron rollers, after a certain amount of use, do attain also a certain and sufficient roughness of surface. The porcelain rollers have an advantage in not being liable to the rust which would affect the surface of the iron rollers if they were for some time out of use and were unprotected, but against this is to be put the liability to fracture, from which iron rollers are free.

The dimensions of rollers, especially in roller-mills when pressure is applied, seem to be fixed within narrow limits. In order to accomplish a large amount of duty the inclination would be to construct the rollers as large as possible; but experience has shown, having regard to the size of the grain or semolina to be ground, and the desirable period of contact with the rollers, that the rollers should be of a diameter of between 9 inches and 12 inches. The angle formed by the approach of the surfaces of the two rollers is of importance with smooth rollers, for if it be too great the material may not be drawn between the grinding surfaces. As to the length of the rollers other considerations limit it. The surfaces must be absolutely true, and the longer the roller the greater is the difficulty of getting perfectly true surfaces, and also the greater the difficulty of obtaining homogeneity. The manufacturer is thus unwilling to incur the risk of failure in attempting to make very long rollers. And in roller-mills, where the work requires much crushing, there is always great difficulty in contriving an adjustment that will keep very long rollers quite parallel to each other when heavy pressure is brought to bear through them on the material to be ground; and as the pressure on the bearings is in proportion to the length of the working surfaces of the rollers, it is not surprising that in practice it has been found impossible to run the larger rollers, exerting the highest crushing power required on the material to be ground, without causing the journals of the rollers to heat to a great extent, and, this consideration apart, that the mill thus constructed absorbed an inconvenient amount of power to drive it. The length of rollers in the best machines working with pressure is therefore limited to about 15 inches, but rollers so long as 30 inches are in use in the case of grooved rollers working without pressure.

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The surface of the rollers is either smooth or grooved. If smooth the highest finish of the surface is demanded. If grooved, the object of the groove being to obtain a cutting edge, it is important that the form of the groove (as well as the material of the roller) should be adapted to keep up a sharp edge; the edges are intended to cut or break the interior of the grain into small fragments, and to scrape the bran clean. If the edges of the grooves be sharp this object is attained; if they be blunt, the cutting action becomes a bruising one, and the effect is that flour is made instead of the semolina which is desired. The number of grooves varies from eighteen to thirty-five per inch. Some rollers have been constructed with rounded grooves or corrugations, the object being to avoid cutting up the bran, and these may succeed with tender wheats, and when it is proposed to obtain flour and not semolina. The grooving varies considerably as to the width of the grooves, and as to their depths according to the work to be done; some grooving is parallel with the axis of the roller, some is spiral. The spiral grooving produces a scissors-like action. The spindles of the rollers should be of large diameter and the journals long; it may here be mentioned that the frames, bearings and carriages should be of very solid construction, amply provided with means of lubrication, and well protected against the entrance of dust, and that all parts should be readily accessible.

The most simple form of roller-mill is that in which a pair of rollers work horizontally side by side; to these is frequently added a second pair. Another form of frame contains three rollers operating as two pairs, the rollers being one above the other, and the middle roller being common to each pair. Rollers work either with or without pressure. Grooved rollers may do their work with or without pressure; smooth rollers can do their work only with pressure. Grooved rollers working with pressure must be arranged so that they cannot approach each other so nearly as to touch, for if in contact the edges of the grooving would be destroyed.

The pressure should be of an elastic kind so as to allow the roller to recede in case of an ungrindable object falling by accident between the rollers. The power of regulation of the pressure must permit delicate adjustment of increase or decrease from time to time, and admit of its instant removal or application up to a known fixed point. It is most important that the amount of pressure should be constant. It must also be exactly alike at each end of and at all points of the working surface of the rollers. Various contrivances have been adopted to apply the pressure, and

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in all cases the object is gained by fitting one or both the rollers working together with movable bearings. These are operated upon either alone or in combination by wedges, screws, springs, and levers. It is impossible in a short Paper to describe in detail the various plans, or to compare their merits or demerits. The weak points are speedily found out after a short experience in actual work. Especial notice ought, however, to be directed to the ingenious and excellent contrivance of the anti-friction ring pressure arrangement invented by Mr. Mechwart, which affords the power of applying heavier pressure than any other roller-mill.

It remains to speak of the speed at which the rollers are driven; and this again has been fixed by experiment, and in the best examples appears to be limited to a periphery speed of 5,000 to 5,500 inches per minute, which for a roller of 9 inches diameter requires about two hundred revolutions per minute. In some cases only one roller of a pair is driven, the second roller acting as a cushion against which the corn is pressed, and turning by the friction; this is the case only with smooth-surface rollers, and it is also only smooth-surface rollers that are driven at equal velocities. The effect of even-speeded rollers being only to squeeze what passes between them, it is found that the resultant meal is delivered in flattened cakes; these cakes in all cases require to be rubbed abroad so as to obtain a meal that can be sifted, and for this purpose appliances called "detacheurs" are used either in connection with the roller-mills or as separate machines, which simply break up the small cakes. For breaking up the wheat grains, and for grinding the semolinas, differently speeded rollers are almost universally adopted; and for the reason that as the material to be ground is in contact on the one side with a slow moving surface, and on the other with a fast moving surface, a tearing action is produced which enables the grinding operation to be accomplished with far less pressure than when the squeezing action is alone relied on. The difference in the speed of the rollers varies according to the material to be dealt with. The proportions of 4 to 5, 3 to 2, and of 2, 3, 4, 5 to 1 are common differences; while one roller-mill has been constructed in which the fast roller runs at about five hundred per minute, and the second roller is arranged to run at two and a half revolutions per minute, but so that the contiguous surfaces of the two rollers revolve in opposite directions.

It is most important that the details of the feed to the rollers should be arranged so as to allow of delicate regulation as to quantity, absolute evenness for the whole length of the roller,

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regularity of flow, and for instant stoppage. The machines are in all cases driven by belts; in some roller-mills the secondary motions are created by belts, in others by geared wheels. In practical effect there does not appear to be any difference between these modes.

Such are the general features of roller-mills, and there are several types in the market which, in a greater or less degree, satisfy all the conditions required. Every one of them has probably its weak point; and, provided that the material, size, and speed of the rollers are alike, the pressure that can be applied to them without heating the bearings is the element that determines the amount of work that can be performed by the roller-mill; and that mill is best which, all other things being equal, will do the most duty in a given time.

It must not be supposed that the substitution of roller-mills for millstones is a simple matter of using one machine in place of another. On the contrary, no small amount of skill, in adjusting a roller-mill to the performance of the work, is required, and still greater skill in arranging a series of them to perform the work of gradual reduction. The roller-mill is, in point of fact, a tool that requires the intelligence of a skilful brain to use it efficiently. Whatever doubts there may be as to the advisability of the general adoption of the system of gradual reduction by roller-mills, experience has shown that a roller-mill is an excellent machine for grinding semolina or middlings, especially if the purification of them is not quite perfect.

The most recent development of roller-milling is in the direction of substituting rollers for millstones in the low-grinding, or half-high-grinding system. A roller-mill has been brought out by Mr. J. A. A. Buchholz, consisting of three grooved rollers acting as two pairs, and under great pressure the wheat is reduced to flour and semolina in two operations. The wheat is fed between the first pair, which crush it severely; thence it passes to a sieve which takes out all the finer parts of the meal; what remains is carried to the second pair of rollers, which complete the grinding operation. The machines are in use in some large mills. For a dozen years or more combinations of as many as six or eight pairs of rollers with intermediate sifting machinery in one frame have been worked, and lately several roller-mills of this type have been introduced. The complication of all the systems of grinding by roller-mills is what stands in the way of their general adoption, and the desideratum is, some form of mill which, while avoiding the defects of the millstones, will yet retain their simplicity of

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action: in fact, a machine that will at one operation obtain the same results as now require half a dozen.

It remains to speak of disintegrators. These, in various forms, have been tried for flour-making, but not with success. The violence of the operation, and the grinding or breaking of the bran which ensues, must inevitably spoil the quality of flour made by a disintegrator from any but tough-skinned wheats.

A combination of roller-mills and a modified disintegrator has been adopted by Nagel and Kaemp. The process consists in squeezing the wheat between smooth rollers running at equal speeds, thus fracturing the flour-bearing interior, which, when subjected to the dismembrator flies to pieces, the action of the dismembrator not being great enough to break up the bran. The process is repeated till the bran is cleaned. The semolina is reduced to flour in the ordinary way. Employed on some sorts of wheats the process is said to give good results.

One of the most important benefits arising from the use of rollers is undoubtedly the power they confer on the miller of removing, partly or entirely, at one stage or other of the grinding process, the germ of the wheat corn. Its presence in flour injures the quality, but it is an admirable food for cattle. If it escape all the preliminary stages, and appears in fragments or entire in the semolina, the smooth rollers flatten it out, and it can be easily removed by sifting. In millstone grinding it is cut up and mixed with the flour.

3. Sifting or Dressing.

The next machines in order of process are the dressing machines, which are used for sifting meal, semolinas, and flours. Up to about thirty years ago, the machine most generally employed was a cylinder formed of wire gauze, which was supported by wooden ribs, set in a slightly slanting position, inside which revolved, at a high speed, a shaft furnished with brushes which touched the wire. The meal was introduced at the upper end of the cylinder, and by the rotation of the brushes the floury particles were driven through the meshes of the gauze, while the offal, thoroughly freed from flour, escaped at the lower end.

About 1850, machines came into use in this country consisting of light reels of wooden laths, six to eight-sided, about 3 feet or 3 feet 6 inches in diameter, and from 12 feet to 35 feet in length, covered with silk gauze, through which the flour was sifted by causing the reel to rotate slowly so that the meal was lifted high

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enough to have a clear fall upon the silk on the lower side of the reel. This was a much gentler operation than the wire cylinder and brush, and had the advantage that the light fine particles of bran were not forced through the meshes, as they were with the brush machine; it had the disadvantage, however, of requiring much larger space than the old machines to do the same amount of work. To overcome this inconvenience there have been lately introduced centrifugal dressing machines. In these, cylinders of short length, covered with silk, are used, which are made to rotate; and the sifting is accomplished by throwing the meal lightly against the silk by means of beaters, which revolve at a somewhat rapid speed inside the cylinder of silk, with a certain space between the beaters and the silk. The rotation of the cylinder causes the meal to fall away from the silk as it reaches the upper side of the machine, to be again and again thrown against the silk, until, the fine particles having passed through the meshes of the gauze, the offal escapes at the tail. The advantage of the machines is the small space occupied in proportion to the work accomplished; while their drawbacks are, the wear and tear of silk, which is greater than in the reel machines. From their compact construction they are of much value, though in mills where there is ample available space they will not supersede the simple reel for dressing meal ground by millstones. But the use of the centrifugal machine is almost essential in dealing with meal ground from semolina by smooth-surface rollers; for although differential speed be adopted for the rollers, there is still a slight tendency to cake in the meal, especially in damp climates, and when tender wheats are used; and the beating of the centrifugal machine is in most cases sufficient to disintegrate the cakes, and thus to avoid the employment of a detacheur as a part of the roller-mill, or as a separate machine.

4. Semolina or Middlings Purifying.

Passing from the dressing machinery to the next process, the most important machine of recent introduction is the purifier, so called because its purpose is to purify the semolinas, or middlings, from the small particles of bran which are mixed up with them, and to separate according to their density the lighter from the heavier semolinas. This work cannot be accomplished by any mere sifting operation, because where the gritty particles of semolina pass, then the bran particles, being of the same size, will pass also. But the bran particles, and the inferior quality of semolina being specifically

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lighter than the best and purest semolina, advantage is taken of this characteristic to divide them. The operation is assisted by the difference between the semolinas and bran in shape; the former are spheres or polyhedrons; the latter is always flat.

Until the invention and adoption of the purifiers the middlings, which are now recognised as the most valuable part of the grain for flour-making purposes, were commonly sold for making coarse biscuits, and even for cattle and pig feeding; simply because there was no known method of separating the branny particles from the good semolina or middlings. And in this country, the only system for the production of fine white flour was by the use of the highest qualities of white wheats ground and dressed very finely. These wheats then brought a considerably higher price in the market than red wheats, which in all other respects, except in the colour of the bread yielded by the flour made from them, were superior in quality; but the particles of the red or brown skin made the bread dark. With the use of the purifiers, better bread can be made from these red wheats than from the white wheats, because the discolouring particles of bran do not enter the flour, and consequently white wheats no longer fetch the high relative prices which they formerly commanded. But it must be borne in mind that it is only a power of more complete separation of the meal which these machines confer on the miller, and that if he be enabled by their use to manufacture a fine flour from the best of the materials which the machines separate for him, he still has to find a market for the inferior products of the machine. So that on the whole, though the advantages of the employment of purifiers are great in the manufacture of fine flour, yet, under the conditions on which in the United Kingdom the business of the miller is carried on, there are drawbacks which should make him cautious in adopting too extensively the use of this valuable machine. In all high-grinding and gradual-reduction processes its extensive use is indispensable.

The variety of purifiers in the market is very great, but they can all be classified under the following heads:—

(1.) Wind machines depending on the exposure of the material to currents of air.

(2.) Centrifugal machines where the separation is accomplished by centrifugal force, in combination with currents of air.

(3.) Sieve machines where the separation is accomplished by oscillating sieves in combination with currents of air.

The germ of the first-named class is the old Vienna wind

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machine, in which the semolina was exposed to a slight blast of wind, produced by a fan, and it was so contrived that the thin stream of impure semolina in its passage through the machine was two or three times subjected to the current of air which was sufficient to blow away some of the light particles into divisions prepared for them. But the semolina had to be repeatedly passed through the machine to make a good separation, and the work was never under complete control. Yet for some forty or fifty years this was the only purifier in use, and its employment was confined to the Austrian mills.

A great improvement was effected, still following the lines of this machine, by substituting exhaust for blast, and Charles Haggenmacher, of Budapest, contrived a series of machines of this type, which leave nothing to be desired. The stream of semolina is made to fall through a vertical rectangular trunk or pipe, fitted with baffling boards so fixed that in its descent the stream is caused to cross and recross repeatedly from one side of the pipe to the other, and a current of wind is drawn upwards through the pipe, so that as the semolina falls it is subjected to the action of the current again and again; the current is capable of being so regulated that it can be made to suck away either the whole stream of semolina, or only the lightest particles of bran, or any intermediate proportion; while, by an arrangement of air-passages and valves it is most ingeniously contrived that what has been sucked away is by a similar exposure to air-currents divided and redivided, so that the operator has the most complete control over the amount of purification of the semolina which he may desire to effect. The machines are very compact, and complete the work of purifying at one passage of the semolina through the machines. They are used universally in Austria and Hungary, but have not been extensively used in this country, because they are adapted only for the larger sizes of semolinas, and are not fitted for the small sizes, or middlings, which British mills produce.

In the second class in which the purification is accomplished by centrifugal force in combination with currents of air, the machines vary only in details of construction, the principle being in all cases alike. The material to be separated is brought by a pipe to the centre of a horizontal revolving disk, by which it is thrown off in a circular shower depending on the speed of the disk and the specific weight of the semolina for its range. The heavier and better particles of semolina fly the farthest, the poorer and less heavy particles less far, and so in proportion, the quite light bran

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particles falling very near the disk. Receptacles with concentric divisions are constructed at various distances from the centre of the disk, into which the various qualities are thrown; but to assist the operation a current of air is established by an exhaust fan drawing downwards and towards the centre through the scattered semolina, which not only draws away with it the very lightest particles but also, by resisting the flight of the particles of medium weight, tends to deposit them in the inner divisions.

The third class of machine finds the greatest favour in the United Kingdom and America chiefly because it is best adapted to treat the smaller-sized semolinas. The principle of this type of machine is that it treats the semolina by running it over a long narrow sieve, which has a rapid oscillating or joggling motion; the semolina which falls on the sieve at the upper end is by this motion gently carried forward to the lower end of the sieve, and at the same time the result of the action is to cause all the light particles to find their way to the top of the stream, while the heavier particles sink to the surface of the sieve; the appearance of the stream in motion is as if slight ebullition was going on in it. The sieve is placed in a large chamber or case, and so connected with the sides as to form a horizontal diaphragm, dividing the case into two nearly equal parts; it is covered with silk gauze with meshes graduated to the size of the semolinas under treatment, and, as just stated, the action of the sieve of itself tends to bring the particles of semolina down to the surface of the sieve through which they are intended to fall, and to float the light particles on the top of the stream. It remains to cause a current of air to pass upwards through the silk and through the layer of semolina on it, so balanced that it is just sufficient to keep any light particles from passing through the meshes of the sieve, while it is not so strong as to prevent the heavy particles from falling through. The current sweeps upwards through the chamber formed above the sieve to an outlet, and carries with it the very lightest and finest particles, and deposits them in a room constructed for the purpose, while the somewhat heavier of the branny particles are kept from passing through the meshes of the sieve, and float on the mass until they emerge over the tail into a receptacle prepared for them. The purified semolina that falls into the chamber below the sieve is collected and carried out of the machine by a worm. The management of the air-current is the great point of importance, and has taxed to the utmost the ingenuity of inventors. The current is produced either by a blast fan in connection with the chamber under the sieve, or by

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exhausting the chamber above the sieve, or by both in combination, by making appropriate inlets and outlets in each case. The great difficulty has been to obtain an even pressure of air over the whole area of the underside of the sieve, graduated and capable of being regulated according to the nature of the semolina and to its quantity, and capable of variation at different parts of the sieve; and a pressure which, while sufficient for its purpose, is not so great as to carry away at the outlet of the air-current, and thus waste, any large quantity of material. A second point is the difficulty of keeping the meshes of the sieve open, as they are prone to be stopped up by particles just large enough to enter the meshes and not large enough to pass through. Gentle brushing by travelling brushes has been adopted to overcome this difficulty, by which the sieve is kept open. The practical working of the purifiers has also developed innumerable minor impediments, which by one inventor or another have been conquered, and the best machines now in the market are capable of successfully purifying the finest and softest middlings, even if they approach in character to flour, without material waste. This type of machine has its origin in a French machine, constructed by Cabane. But the Americans have greatly improved on the original, and have taken out numerous patents for details and improvements of purifiers during the last few years. It is obvious that in all purifiers, as the separation is made by gentle air-currents, the particles to be separated must not differ much in size. It is therefore necessary to provide a series of purifiers in mills, to each of which should be allotted a separate size of semolina. The semolinas are sized by sifting through silk gauze. An even feed to the machines is also of great importance.

The use of purifiers is comparatively small in this country, because the conditions of the trade are not adapted generally for the manufacture of the finest flour. In Hungary and in America, however, there are to be found regular systems of machines whereby the semolina is purified and repurified, and whereby what is rejected from the first purification is again and again treated. This involves the employment of a very large number of purifiers, a number indeed so great that it is impossible to find space for them in a mill, unless it has been specially built for the purpose. One of the chief obstacles with millers to the adoption of any system of which purification and repeated grindings and dressings form a part is very often that the buildings at their command do not afford the necessary space. But if fine flours are to be made, abundance of purifying power is

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an absolute necessity, and the purifier may claim to be a more important machine than the roller-mill in any modern process; for the work of the latter may be performed by the millstone, while without the purifier neither millstone nor roller-mill can make the finest flours.

Such are the features of the principal machines in use in modern corn-mills; and the property that is common to all of them is that no one machine of the series is confined to the performance of one exact and particular duty; but in every case, and at every stage of the manufacture of flour, there is abundant freedom, and indeed actual need, for the display of skill on the part of the operator in the control and regulation of the duty thrown on each machine. Thus, in the grinding operations, whether by millstones or by rollers, the utmost skill is required to adapt the treatment both to the quality and character of wheat in use, and to the ultimate result in flour which it is desired to attain. And upon a very little difference in this operation may depend the profit or loss of the miller. So in the matter of dressing the meal, the variations of practice are most numerous, some beginning where others leave off, and *vice versâ*. Again, in handling purifiers, apparently the most opposite opinions prevail as to the best mode of procedure. The mere possession of one machine, or any series of machines, does not constitute a process or a system, as each and all may be handled in a great variety of ways, and the same machines can be made to produce the most varied results. The handling of the machines described is, therefore, purely a practical and technical matter upon which no hard and fast rules can be laid down.

Again, the arrangement and position of the machines in the mill building affords scope for much ingenuity. In this matter, however, one rule must predominate over all other considerations, viz., that the material in process of manufacture must not require to be moved by hand-labour at any stage from its reception into the mill until it is finally packed in the bags in which it is to be delivered to the consumer. Appliances in the way of endless belting, worms, conveyers, pneumatic apparatus, &c., are available for carrying in horizontal directions, while the elevator, consisting of cups fixed on an endless band, serves for lifting in a vertical direction.

Wherever practicable it is always sought to so arrange that the stuff may run by gravity from one machine to another, and it is for this reason that the buildings for flour-mills are generally lofty.

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Sifting operations perform a great part in the manufacture, and the distinctions in size that it is necessary to make are often of a minute kind. The adoption of silk gauze as the material for sifting has alone rendered these fine distinctions possible; and a sketch of modern milling would be incomplete which did not give the manufacturers of these silk cloths the highest credit for the beauty and regularity of their fabrics. When it is considered that they are called upon to supply silk cloth containing certain definite and known numbers of holes to the square inch, varying from two hundred and fifty up to about twenty-three thousand, and that in the higher numbers the holes are quite microscopical though regular in size, while at the same time the gauze has to be of sufficient strength to bear the strain that is put upon it, the difficulty of their task can be conceived. The best quality of silk gauzes is manufactured in Switzerland.

Finally, in spite of agitation in the direction of persuading people to eat brown bread or bread containing the skin of the grain, the tendency, though not moving rapidly, is clear and marked on the observation of a series of years towards the consumption of finer and whiter bread by the masses. Popular taste fluctuates, but should it continue to move in the same direction a steady spread of the use of high-grinding systems may be looked for.

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(*Paper No. 1874.*)

"Modern Flour-Milling in England."[1]

By HENRY SIMON.

IMPORTANCE OF FLOUR-MILLING INDUSTRY.

THE importance of the trade done by the flour mills of the United Kingdom is scarcely appreciated by the public.

A mill has lately been started at Belfast fitted entirely with modern machinery, which will be described further on, and arranged on the system recommended by the Author. This mill is capable of grinding about 8 tons of wheat per hour, or, if working day and night for twenty hours, a daily total of about 100 tons, representing a railway train composed of about twelve wagons for bringing the wheat, and another daily railway train, composed of about as many wagons, for taking away the flour and bran.

Supposing such a mill to be in full work for three hundred days in the year, the money paid for wheat would come to about £300,000, and for the flour ground and offals a similar sum, in addition to a margin of profit, would be realised. The total of the money turned over by such a concern would therefore amount to considerably over £600,000 sterling per annum.

One London firm is known to sell at present about nine thousand bags of flour per week, which, taken at an average price of, say only £1 16*s*., and adding thereto a proportional amount of money for the offals, is about £1,000,000 annually, or, roughly speaking, and including the money paid for the wheat, a turn over of £2,000,000 in a year.

A considerable number of important milling establishments exist at Budapest, in Hungary, where, owing to a fortunate concourse of favourable circumstances, this industry had attained, many years ago, a high state of development, both as to quantity and quality of its products, and principally with regard to quality, considerably in advance of all other countries. These mills belong to companies which, up to a comparatively short time ago, paid enormous dividends, reaching sometimes 40 per cent. per annum. One establishment has, during the last ten years, paid a yearly

[1] The discussion upon this Paper was taken together with that upon the preceding and following ones.

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average of 26·6 per cent. on the capital of about £100,000. The eight principal mills, with a total capital of £580,000, have, during the last ten years, paid an average of 14·2 per cent. They are all roller-mills.

The superior qualities of flour produced by these Hungarian mills are extensively exported, and the amount of such flour reaching the United Kingdom has been increasing for several years, until the last year or two, when a partial stop was put to it by the succession of splendid and abundant harvests in the United States, and the great impetus thereby given to the development of the manufacture of flour in that country, and the consequent imports into the United Kingdom.[1]

For many years English housewives, English bakers, and even English millers, have been accustomed to buy the highest grades of Hungarian flour for mixing with the darker flour produced in this country, and an increasing demand for superior well-cleaned and white flour has thus gradually been established, which it is as yet difficult for most English millers to respond to.

The well-known spirit of enterprise of the people of the United States, fostered as it has been by the extraordinary good harvests of the last few years, has given to their milling industry an unprecedented development.[2]

One of the best known flour-mill establishments in America is that of Governor Washburn, of Minneapolis. The aggregate capacity of his mills amounts to about six thousand barrels per day.[3] His establishments are most substantial constructions of grey limestone, and are equipped with the best class of modern machinery. Quite recently some of the machinery described lower down and equal to that largely introduced in this country by the Author, has been erected, and tested with very

[1] These imports have been fostered and facilitated by excellent trade customs and carrying arrangements. For a description see "Flour Mills of Minneapolis," in the *Times* of the 3rd of February 1882. The through carriage for flour to Liverpool, Glasgow, or London, ranges as low as 1*s.* 9*d.* to 2*s.* per 100 lbs. It is interesting to note that the large imports of grain facilitate the export of iron by affording exceedingly low return freights. Large American orders for pig iron are now (February 1882) said to await execution, because of the difficulty to secure low freights to the United States on account of the considerably decreased imports of grain in consequence of the American harvest being 30 per cent. less than in 1881.

[2] To give an idea of the dimensions of American grain traffic, it may be mentioned that at Chicago alone sometimes two thousand five hundred railway wagons loaded with grain arrive in a single day, stated to represent railway trains of a length of 14 English miles.

[3] One barrel is equal to 196 lbs.

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satisfactory results at one of the mills belonging to the firm. The possible yearly turn over of such a mill is between £4,000,000 and £5,000,000 sterling.[1] The manufacture of flour therefore may be said to rank very high in respect of the importance which single establishments may reach.

As to the importance of this industry as a whole the following calculations will best show the magnitude of the interests involved. The total quantity of wheat grown in England in 1880 was about 10,000,000 quarters, and the quantity of wheat imported 12,000,000 quarters. In addition to this total quantity of 22,000,000 quarters, nearly 11,000,000 cwt. of flour were introduced. This represents, roughly, about 15,000,000 cwt., or 3,300,000 quarters of wheat.

The total wheat consumed was therefore equal to slightly over 25,000,000 quarters (of about 500 lbs. each); or taking the number of inhabitants at thirty-five million, a daily consumption of just about 1 lb. of wheat per head, not reckoning other cereals. This total represents a value of about £56,000,000 sterling per year, or over £150,000 per day. The cost of 1 lb. of wheat is about 1*d.* In the retail trade the value of the flour obtained from 1 lb. of wheat may be taken to vary from 1½*d.* to 3*d.*, the latter for the finest brands of Austrian flour.

The total money value of the wheat-flour per head of population is therefore considerably more than 1*d.* per day.

It is interesting to extend this calculation to the whole of Europe with its three hundred and twenty-five million inhabitants, representing at the very least as many lbs. of wheat, or other cereals, to be reduced to flour per day. To illustrate the importance of this daily quantum it may be stated that it would occupy railway trucks to the number of about twenty thousand, occupying a length of, say, 80 miles, requiring, of course, a similar number of wagons for the daily conveyance of the ground products. The daily expenditure for cereals in Europe can therefore be estimated at £1,500,000.

An average ordinary pair of stones (taking into consideration those that are stopped for sharpening or dressing) cannot be estimated to grind more than 18 cwt., or say 4 quarters of wheat, per average day of work. This is equal to 1,200 quarters per year.

Dividing the total quantity of 22,000,000 quarters (of wheat alone) to be ground per year in the United Kingdom by 1,200, the result is eighteen thousand as the probable number of pairs

[1] The flour mills of Minneapolis are said to have a possible daily production of twenty-five thousand seven hundred and fifty barrels of flour.

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of millstones used for wheat. This is by no means too much, seeing that the number of millers in the United Kingdom is estimated by Mr. Chatterton, the Secretary of the National Association of British and Irish Millers, at slightly over ten thousand, but it is likely that there are amongst the ten thousand addresses collected by Mr. Chatterton, a good many dealers in flour styling themselves millers, possibly having a pair of stones for rough grinding, or breaking fodder, &c.

Eighteen thousand pairs of stones, with their necessary dressing machinery, may be taken to require all the year round about 125,000-HP. for driving them.

It will therefore be seen that, not only when considered with regard to the possible size of single establishments, but also when taken as a whole, the manufacture of this staple food deserves to rank in the first line of national industries, and truly did Professor Graham say, in his Cantor lectures on bread-making: "Cereals are, of all the fruits of nature, the most important to man for their invaluable store of flesh-forming and heat-giving principles, the right method of preparing them for his use is one well worthy of the most attentive study."[1]

Moreover, it is certainly a subject of national importance that such a vast amount of valuable material should be treated in the best manner possible, and that all waste in its treatment should be avoided. Reliable results obtained in practice in mills erected by the Author, prove that by a more rational and advanced process of milling, an increase in value per sack of flour of from 2*s.* 6*d.* to 5*s.* is obtained, the total quantity of flour taken out of the grain remaining about the same. That is, the value of the products is increased up to the extent of about 11½ per cent. Of course, such a high increase of profit can only be fully maintained by the miller as long as his competitors do not follow in the improvements. That miller, however, who first starts in a district does positively realise it, provided he has a sale for the superior qualities. It is this latter question which has kept many a miller from making alterations. Nothing was more common some little time ago than to be told by the miller that he could not get one farthing more for flour however beautiful he were to make it. The taste for white flour, however, has now been developed, and even if this were not so, it would still be certain that that miller who gives the best value for the money would at least do the largest trade in his district. It is, of course, out of all question that such

[1] Journal of the Society of Arts, vol. xxviii., p. 89.

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an increase in value as here given could ever be actually realised by the millers on the whole of the wheat ground in England,[1] for competition will in the end reduce their profits, but it is certain that the nation as a whole will be the gainers by obtaining the purer and more digestible food now offered.

It will easily be understood that the more intelligent amongst the British and Irish millers have long since become fully aware of the absolute necessity of improvement, and this conviction is rapidly spreading amongst a continually increasing number of millers. The demand thus created for improved machinery has as usual been met by an ever-increasing supply. So great, indeed, is the variety of machines of every kind now offered, that many a miller is bewildered by their number; all the more so as they are constructed on principles heretofore entirely unknown to the immense majority of millers. The first to feel foreign competition were, of course, those owning mills situated in or near ports. Numbers of such millers in England, Scotland, and Ireland, have been entirely stopped by the import of superior or cheaper American and other flour; and it is the owners of such mills who naturally first became alive to the necessity of doing something to retrieve their position. The average mid-country miller has, until now, been less subjected to such influences, and therefore also less inclined to improve.

The Author has, during the last three years, introduced a special and improved system of flour-milling in about twenty-five British and Irish mills. Of these the greater number are in towns on or near the sea. The same may be said of improvements of old mills by the addition of single machines.

Signs, however, are by no means wanting that this difference is rapidly decreasing, and that the interest in the improvement of the manufacture of our staple food is becoming more general, and this desirable result has certainly been accelerated by the formation of the National Association of British and Irish Millers, by the Papers which have been read and discussed at their annual meetings, and by the International Exhibition of Flour-Milling Machinery originated by that association, and held last year at the Agricultural Hall. This was preceded by the International Exhibition of Milling Machinery in Cincinnati, which was visited by a large party of British and Irish millers.

The above considerations would appear sufficient to justify a description of the fundamental principles and of some details of

[1] On the 22,000,000 quarters ground in England an extra profit of 2*s*. 6*d*. per sack of flour would be £4,000,000 per year.

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the improvements now in course of introduction in a branch of industry so important to the health and wealth of the nation.

The Author does not purpose to enter into a description of milling in all its branches, but presupposes a knowledge of the process of grain-cleaning and grinding as generally applied in this country until now. He will only describe the treatment of the grain after its separation from impurities either mixed with it or adhering to it.

Different Systems of Grinding.

The reduction of the grain into flour may be done either rapidly and roughly or slowly and carefully. The former is effected when the top stone is set near or very close (lower) to the bottom stone. The latter, when the distance between the stones is greater (higher). Hence the former process is called low grinding, and the latter high grinding.

Low grinding has until now been, and to a large extent still is, the rule in this country. On the other hand, the quantities of flour imported from Hungary are produced by high grinding in its strictest sense.

The ordinary country miller desires to get through his work in as short a time as possible. He therefore sets the stones very close, and produces in a short time a considerable quantity of flour; but this flour is dark, because the branny outside and the germ of the grain of wheat in their course through the closely-set, sharp, rubbing surface of the stones, are to a considerable extent likewise reduced into small atoms and mixed with the flour. Flours containing such admixtures in too large a proportion do not keep well, and easily acquire a musty taste. There is this further difficulty in low grinding, that such a rapid and violent process necessarily cannot be carried out without over-heating the materials operated upon, thereby spoiling them to a considerable degree by rendering them liable to dampness, and in consequence of that to the formation of lumps or balls of flour. Great heat has an injurious effect on the glutinous or most valuable parts of the flour,[1] which thereby loses to some extent its strength. "Strength" is that highly appreciated quality of flour which enables it to take up a large quantity of water when being made into dough, and which is the cause of more considerable

[1] Journal of the Society of Arts, vol. xxviii., 1879–80. Cantor Lectures. "The Chemistry of Bread-making." By Professor Graham, D.Sc.

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rising, and the consequent increased digestibility of bread. It has therefore been necessary to invent and use in low grinding complicated and costly apparatus for partly preventing high temperature and its evil consequences. Flour made by the old-fashioned low-grinding process will, for the reasons stated, not keep as well as flour produced by high grinding, and which in Austria therefore often goes by the name of "*dauermehl*," that is, flour that will stand, last, or keep.

In low grinding in Austria, and partly also in England, the wheat used to be damped to make the bran tougher, and less likely to be destroyed by the violent action of the stones. Even to this day many English millers wet or steam the wheat. Whatever good influence this may have on the bran, it is, according to first authorities, highly detrimental to the flour, the gluten being deteriorated by moisture and losing its great and important quality of rising with water during the baking.[1]

High grinding, on the other hand, is carried on without damping or steaming, and under lower temperature, and the blast or suction used in the process of purifying the middlings has also a drying influence; consequently flour thus produced keeps or bakes better.

None but such "*dauermehl*," that is, flour produced by high grinding, could ever become a successful article of export. Of course all the American export flour is produced by high grinding.

The great principle of high grinding is the gradual reduction of the grain into flour. The process is divided into several stages, and the branny particles are carefully separated from the remainder before each further reduction, for it is impossible to work on any parts of the grain to which branny particles adhere without to some extent reducing the bran as well as the floury parts, and thereby discolouring the latter.

The number of reductions in high grinding is carried very far in some Continental mills. Five or six breaks are, however, found by the Author sufficient in roller-mills in ordinary cases in this country.

It is evident that these two processes cannot be divided by a sharp line; in practice they merge into each other. Thus the expression, half-high grinding, is applied to a mill working with a more limited number of reductions, say three or four in roller-

[1] Cantor Lectures. "The Chemistry of Bread-making." By Professor Graham, D.Sc. Journal of the Society of Arts, vol. xxviii., 1879–80. Also Report on flour in Vienna Exhibition. (Mehl, Mehlfabricate und die Maschinen und Apparate der Müllerei und Bäckerei. Bericht von Friedrich Kick. 8vo. Wien, 1873.)

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mills, and it is usual amongst millers to speak of a miller grinding higher or lower according to the number of reductions, separations, and purifications employed by him. The improvements now in progress of introduction in this and other countries are all in the direction of high grinding, and there is this remarkable circumstance connected with it, that such a valued and ancient servant as the millstone is now being rapidly replaced by the roller-mill, a machine entirely different in principle.

It is the high-grinding process with roller-mills which forms the principal subject of the present Paper.

Even low grinding is now being carried out by roller-mills, and certainly with results superior in some respects to low grinding with stones. At the same time these results cannot be compared with those obtained by high grinding with roller-mills, for, whereas the high-grinding system, as practised by the Author in a large number of mills, will give up to about 75 per cent. of flour, of which about one-fifth is of the highest class; low grinding by rollers will not get out of the wheat more than about 68 per cent. of flour, and that of a lower average quality. This, it is true, is counterbalanced to some extent by the advantage of less machinery being required, but even in roller-mills low grinding retains most of its disadvantages, as compared to high grinding. The meal leaving the roller-mills after a low-grinding process is disagreeably hot to the touch, and the flour therefore is necessarily damaged to some extent in its bread-making qualities, the flour is less white, and the percentage of superior flour is much smaller.

Further by high grinding the amount of flour obtained is about 75 per cent., as against only about 68 per cent. by low grinding, being a difference of 7 per cent. so obtained, or about 10 per cent. less on the total quantity of flour produced. Irrespective therefore of the lower quality of flour produced by low grinding, there is the waste of 10 per cent. of flour going into the offals and being sold at a loss. This loss in the course of a year may be sufficient to pay for a complete high-grinding plant on the most approved principles. In a mill grinding 15 cwt. of wheat per hour the loss in low grinding, as against high grinding, may amount to about £3,000 a-year.

High grinding may also be described as that way of manufacturing flour in which, by a gradual reduction of the grain, a maximum of middlings and a minimum of flour is first produced. The middlings are afterwards separated from the branny parts by a process called purifying. After that the middlings are further gradually reduced to flour, and between the several stages of

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reduction of the middlings the process of purifying is repeated as often as necessary.

High grinding originated in Austria, and is there often described as semolina or middlings grinding (*griesmüllerei*).[1] The fundamental principle is to avoid the progress of formation of flour as much as possible, as long as any bran or branny particles, even of the smallest possible removable size, are present. The reason is self-evident, for any action or rubbing brought to bear on branny middlings must necessarily attack both the floury and the branny parts, thus reducing the latter in size, rendering their removal more difficult, and in the case of the very small particles impossible, which means discolouring the flour, reducing it in market value, and leaving indigestible parts in it. High grinding by rollers renders it easier to keep the bad or worthless constituents of the grain out of the flour. By high grinding a greater variety of flours of different qualities and value may be obtained; also a much larger percentage of white, pure flour, and a much smaller percentage of dark flour. But it is a mistake to identify roller-milling with the necessity of selling different classes of flour. Several of the millers for whom the Author has erected mills make but one "straight grade" which is of very much superior quality than possibly could be produced by stones. Every facility thus exists for an intelligent high-grinding miller to adapt the products to the different classes of his customers, and to make those grades of flour out of the wheat that will bring the most money.

To sum up. Low grinding upon the whole may be said to produce comparatively dark and impure flour; high grinding white and pure flour. The former contains impurities ground up with the floury part of the grain. The latter is, as far as possible, cleaned from all matter out of place. Arranging low grinding and high grinding with its intermediate stages at, or rather underneath the lowest stage, is whole meal flour, whilst at the top of the list are the finest brands of Austrian flour, the equal to which are now produced in this country by the advanced milling process to be described.

Evolution of Roller-mills.

Helfenberger and Rollinger, in Switzerland, constructed roller-mills as early as 1825. The rolls were of iron, smooth on their

[1] Interesting condensed data on the early development in Austria of high grinding, and the several machines used in it are to be found in Kick: "Die Mehl-Fabrication," 2nd edition, Leipzig, 1878, pp. 294, 295.

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surface, but the machine was subject to a number of constructive drawbacks, the elimination of which proceeded but very slowly.

For this reason, their application was scarcely more than experimental. Their first practical use on a large scale took place at Budapest, about the year 1839. The roller-mills then used were manufactured by Sulzberger, of Frauenfeld, in Switzerland,[1] for the "Pester Walzmühl Gesellschaft."

They embodied already the important principle of "differential speed," which consists in driving one roller faster than the other. This company is still one of the most important in Pest. Other roller-mills, on a large scale, were not established there until 1874. But most of these use the stone to some extent, to this day, at least for part of the work done in grinding. With rollers of equal diameter, driven at the same speed, the grain or middlings acted upon is made into flakes or cakes, whereas, by the differential speed, a kind of rubbing or scraping action is obtained, pushing the particles of flour off the bran and over each other, thus separating them. It is of great importance not to use more pressure between the rollers than is absolutely necessary for the disintegration of the flour, as unnecessary pressure means unnecessary expense and power, irrespective of the fact that any flakes produced by it must necessarily be reduced again at a further expense of power in the following operations.

Professor Kick, in the new edition of his book on "Flour Making," states that, on theoretical considerations, the power consumed in crushing grain by direct pressure, that is, between smooth rollers, without differential motion, is exactly double that required to reduce grain between fluted rollers with differential motion. This roughly coincides with the results obtained in practice, and experiments have proved that direct pressure, without differential speed, produces about one-third less result than the same pressure with it.

Similar machines were afterwards made by Messrs. Escher, Wyss, and Company, of Zurich. These old rollers are, to some extent, still at work in Budapest. They were expensive machines, with three pairs of rolls, one pair above the other, the two parallel axes of each pair lying in a horizontal plane. The material to be operated upon, fell from a hopper into the space between the

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[1] "Die Mehl-Fabrication," by Professor Kick of Prag, Leipzig, 1878. This at present is the standard book on the manufacture of flour, and it is much to be regretted that a complete translation has not been published. See also "Popular Handbook on Flour-milling," by Gustav Pappenheim, 1878. Vienna.

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first pair, then straight through to the second and third, without being subjected to any intermediate purifying or sifting process.

This is wrong in principle, as those parts reduced to flour by the first operation should immediately be withdrawn, and not undergo further joint treatment under the next pair of rolls, the consequence of which would be a further discoloration of the flour from the branny particles against which they would be rubbed and pressed in the following reduction.

Irrespective, however, of this point, which could easily have been avoided, the rollers, although adjustable as far as their distance was concerned, were during the work kept rigidly in place. This has been found a serious drawback, giving rise to accidents in the case of stones or nails passing through, and interfering, to a considerable degree, with the regularity of the work, for the slightest irregularity of feed would necessarily affect the work upon the material passing through the rollers. Greater pressure would be exerted by the rollers with a bigger feed, less or no pressure with an insufficient feed.

It was a decided step in advance when Mr. Friedrich Wegmann, then a miller in Naples, suggested, in the year 1873, a construction freeing the rollers from rigid pressure, by fixing the journals of one of the rollers in levers, on which a weight exerted a continuous pressure that could easily be regulated, either by the alteration of the weight or of its position on the lever.

Later on others suggested spring-pressure instead of weights, and it is this which is now almost universally used in the different roller-mills in Europe and in the United States.

Mr. Wegmann made one other important suggestion, namely, the use, for rollers, of porcelain instead of iron. These two alterations together gave an extraordinary impetus to the introduction of roller-mills, and for a long time it seemed that porcelain would carry the day in taking the place of iron. Several thousand of such porcelain rollers, gradually improved in their mechanical details, have been sold, and there is not the slightest doubt that in some cases their use gives excellent results. It is, however, evident that the surface of unglazed porcelain stands, to some extent in its texture, between that of chilled iron and of the ordinary French burrstone. The roughness of the porcelain is, of course, produced by small pores, each of which, when the roller is ground to a fine surface, must have cutting edges, which increase the rasping or rubbing action on the particles of bran and flour together. So fine are the particles of bran produced in this way, that by no process of purification or sifting can they afterwards be with-

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drawn from the flour. Smooth chilled-iron rollers, on the contrary, do not reduce the branny particles in size, but flatten them out and facilitate their withdrawal by purification, by sifting, or by dressing. It must therefore be maintained, and the results of practice would seem to bear this out, that similar to the nature of the surface employed, the results produced by porcelain rollers are likewise standing somewhere between those produced by stones and those produced by chilled rollers. The branny particles are doubtlessly more attacked by the porcelain than by the chilled iron; hence a slightly darker colour of the flour obtained, and also an increase in the degree of heat produced during the process.

A further serious drawback to porcelain is that it wears away in a comparatively short time, while chilled rollers have scarcely ever yet been worn out, unless made of bad material. Furthermore, porcelain rollers crack occasionally, and get loose on the iron core or axis on which they have to be fixed.

In these last two respects they have been improved by Mr. Wegmann and his manufacturers, the mechanical works of Oerlikon, in Switzerland. It may be mentioned that all attempts to make porcelain do for the first process, namely, that of granulating the grain, have necessarily failed, as small corrugations of porcelain cannot be made to stand, whereas well-made chilled iron corrugated, or finely-grooved rollers, will stand severe work for several years, and can then be easily recut to stand again for another series of years. The expense of recutting is small, and, costing only about 15*s.* to 20*s.* per roller, is certainly unimportant.

The function of porcelain roller-mills, in such places where they exist, ought to be the reduction of the finest middlings or semolina, which contain almost no branny particles, and in such cases they give useful results.

In Budapest, which may be considered the cradle of roller-milling, and in Europe as by far the most important place for it, the use of porcelain roller-mills has been almost entirely discontinued, and the vexed question of the comparative merits of porcelain or iron has been decided in favour of chilled iron. Not one of the enormous establishments of that town is using porcelain roller-mills to any large extent. The same may be said of the bulk of recent establishments in other parts of the Austrian empire. Everybody uses chilled iron. Many of these chilled-iron roller-mills are constructed by Ganz and Company, Limited, of Budapest. This firm had for many years made a speciality of chilled-iron castings, principally railway wheels, which were used

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in the Austro-Hungarian empire and the neighbouring States, with good results, under the railway goods wagons. It was natural for these works to take up the successful manufacture of chilled rollers, in which they soon obtained a leading place. They have now sold in Europe and America several thousand of their rollers. At the same time, other makers in Austria and Switzerland began the manufacture of roller-mills, with various degrees of success; all more or less differing in arrangement and mechanical detail.

It has been said by the advocates of porcelain rollers, that iron rollers communicate a bluish tone to the flour, and that the carbon of the iron, continually exuding, is at the bottom of this. As this idea has got hold, to a considerable extent, of the minds of "practical" men, it may be well not to ignore it, but to refute this extraordinary assertion.

A roller, as used, for instance, in the Daverio mill, which the Author employs almost exclusively in the mills constructed by him in this country, is about 9 inches in diameter, and weighs about 1 cwt. The quantity of carbon contained in 1 cwt. of iron is in itself, of course, insignificant, and could not, even if the chilled iron surface could exude it to some degree, continue for a long time to spoil flour. It is, however, a well authenticated fact that in chilled iron all carbon is in a chemically combined state. Dr. Percy, in his work on iron and steel, says:—"The mode of existence of carbon in iron is in great measure determined by the conditions of solidification after complete fusion, and the temperature at which fusion has been effected. Rapid solidification favours the retention of carbon in the combined state, and by this means it is possible to convert characteristic grey iron into perfectly white iron. Thus by pouring liquid grey cast iron into a cold metallic mould, so as to cause the most sudden cooling possible, the exterior of the solid iron, where it comes in direct contact with the mould, will be found to be in the state of white iron, while the interior will be in the state of grey iron. This principle is extensively employed in practice, in the process known as chill-casting. It is adopted when it is desirable to render the surface extremely hard, white iron being intensely hard as compared with grey iron."[1] And further, on speaking of the analysis he had made of chilled cast iron, he says:—"The outer white iron had a specific gravity of 7·5467, and contained 5·0929 per cent. of carbon wholly in the combined state."[2]

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[1] Metallurgy. "Iron and Steel," p. 117.
[2] *Ibid.*, p. 130.

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The driving of roller-mills has been attempted in different ways. In the earlier period of roller-milling it was usual to drive one roll either by strap or gearing, and to communicate the motion to the other roll simply by contact or by the pressure exerted on the material during grinding. It has, however, been found that this was not the way to obtain reliable and regular results, as the thickness of the feed or material acted upon necessarily influences in this case the number of revolutions of the contact-driven roll. It is therefore now usual amongst makers of good roller-mills to drive both rolls by geared wheels, giving the latter such proportions as to obtain the exact differential speed desired. It may here be stated that for this purpose wheels with slightly V-shaped teeth give excellent results if the shape and curve of these teeth are carefully attended to. In that case they go quietly and smoothly, and wear well; no wheels on the other hand wear so badly as this class if made by rule of thumb.

As not every one is skilful in constructing noiseless wheel-gearing, it has often been attempted to do away with wheels altogether, and to use belts only for driving the rolls directly. The seeming smoothness and noiselessness of belt-driven rolls is indeed very seductive to the looker-on, and there is scarcely an important constructor of roller-mills in Europe who has not at one period tried this device. It is, however, now well understood that there are most serious objections to belt-driven rollers, and the Author has lately had reliable reports from the United States, where during the rapid introduction of roller-milling in the last few years a considerable number of belt-driven rolls had been constructed, that the users in the large mills are sorry to have spent their money on these machines, which have the following drawbacks amongst others.

The ratio of differential speed is not reliable, for with any considerable increase in the feed of such a roller-mill the belts are liable to slip. Now in high grinding everything depends on securing rigid regularity in all the work done in the mill, and the necessity for this has increased a hundredfold since the manufacture of flour by roller-mills has been carried on in an absolutely automatic way.

In high grinding in Austro-Hungary and Germany it has heretofore been usual for the miller to exercise a continued and scrupulous watchfulness as to the looks and value of the many different products obtained in this process, and as to the way in which they have to be sorted and drawn together to produce certain classes of flour.

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At present, however, at all events in England and America, few millers are desirous of exercising this watchfulness, and it is now usual to construct the mills on the automatic plan; that is to say, the wheat goes in at one end of the mill, and the desired number of classes of flour and offal are taken off at the other end without that careful supervision in the intermediate processes which was formerly absolutely necessary, but which in an automatic plant is usually required to a much smaller extent, except for some time when a change is being made from one class of wheat to another.

Irrespective, however, of this grave objection to belt-driving, there are constructive drawbacks of nearly as important a nature. The belts, to ensure regular work, must be kept very tight; special apparatus for tightening them has to be applied and to be looked after. Now tight belts in a fast running machine consume a great deal of power, and use the brasses up very quickly. This again causes trouble in resetting rolls and expense for new brasses. The driving of rolls by belts has therefore upon the whole been discontinued in Europe.

The number of revolutions of roller-mills vary a good deal. The Author uses for smooth rollers about two hundred for the fast centre roller, and about one hundred and seventy for the two slower rolls; and for grooved rolls, according to the work, from one hundred and sixty to about two hundred for the slow roll, with a differential speed varying from two to three times that number or more for the two fast rollers.

According to the intended use of roller-mills the surfaces of the rollers are either left smooth or they are grooved or fluted. Smooth rollers are mostly used for the reduction of semolina or middlings into flour. For the cracking of the grain and the scraping of the floury parts from the inside of the bran, fluted rollers are employed.

Much variety of opinion existed in the beginning, and to a certain degree still exists, as to the best shape of grooves and their relative position to the centre line of the roller. The claims put in by certain patentees for the advantages which slightly different shapes of grooves present, are in most instances much exaggerated. The Author has found that grooves shaped something like those shown in Plate 7, Fig. 3, give the best results. The flutes with rounded edges at present used in some American mills have given bad results; they had long before been tried and discarded in Europe, and are now being discarded in the United States, the Author knowing important cases where the rolls have been thrown out and replaced by the ordinary sharp-

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cornered flute. Indeed, anyone acquainted with the fundamental principle of high grinding must have seen that the grain passing between rollers provided with rounded flutes is subjected to a force more pertaining to the nature of a squeeze, and that in such a process necessarily smaller particles, that is to say, more break-flour will be produced than when the grain passes between sharp-edged flutes. This has been proved by practice, and as the production of flour during the granulating process is the very thing to be most carefully avoided in high grinding, the use of rounded flutes is rapidly dying out.

The number of grooves to an inch of roller-surface varies according to the work to be done by the rollers; the best makers use from ten to twenty-five or even more grooves to the inch.

With regard to the twist of the grooves, the angle adopted in ordinary cases by the Author is about 15°. It is, however, a matter of opinion whether, for instance, in the first break better results are not obtained by having the grooves parallel to the axis of the roller.[1]

The action of a pair of rolls with twisted grooves is more scissor-like.

Now in the first break of grain the great object is, if possible, only to crack the grain of wheat across its natural crease, or figuratively speaking, to open the two halves of the grain like a book. In this case the often large quantity of dust and dirt included in the crease, and the germ which is so detrimental to the keeping and baking quality of flour, fall out and can be separated by sifting machinery.

Similar considerations apply to some of the following reductions of the wheat grain, principally in such country or neighbourhood where, as in England, a general prejudice exists against bran cut into small fragments. The English miller desires to produce bran in large flakes, as the farmer who buys it for feeding purposes prefers it so. (In other countries small bran is preferred by the farmers.) This being so, the use of groves parallel to the axis might even for bran-cleaning (*i.e.* the last scraping of flour off the inside of the bran) be commendable. One of the principal reasons for the spiral position of the grooves seems to have been the desire of avoiding the possibility of the grooves interlocking, and thus damaging themselves in case of the rollers approaching too near each other.

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[1] Spirally fluted roller-mills were patented in England as early as 1850. (See Leggett, No. 13065.)

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In a new and a particularly well-constructed machine this danger is of course small, so long as the brasses do not wear considerably, or as the machine is carefully and attentively handled. Grooved roller-mills should be so constructed that the rollers can never quite touch each other.

A machine of entirely different construction, which for a time created great interest amongst millers, was Carr's well-known disintegrator. Persevering attempts to adapt it for the production of flour have been made, principally by Messrs. Gibson and Walker, a milling firm in Edinburgh, but with, as far as is known, not very favourable results.

Mr. Toufflin, the French licensee of the Carr disintegrator, seems to have succeeded the best. He is said to wet the wheat before putting it into the disintegrator, in order to make the bran tougher. This is the best proof that Professor Kick is right in classing this process with low grinding, of which wetting has always been a distinctive feature. It is a fact that such percentages of superior flour are not obtainable by this process as by high grinding. On the other hand very clean bran, and necessarily as a consequence as large a total quantity of flour is produced as by any other good milling process; but irrespective of this consideration the disintegrator, as is well known, consumes an exorbitant amount of power, and consequently is expensive to work. Having to be driven at a high speed, it creates great heat, and is looked on with suspicion by fire insurance companies.

The disintegrator (Plate 7, Fig. 4) is the principal machine used in a milling system known by the name of the Messrs. Nagel and Kaemp (Hamburg). The following is a short extract of a description published by that firm.

Nagel and Kaemp's System.

The machines used are:—

(1.) Chilled-iron roller-mills, the rolls of which work at equal speeds or without differential motion, the surfaces being smooth. The pressure of the rolls one upon another may be regulated by an arrangement of a lever and springs.

(2.) Dismembrators, which are machines closely allied to the disintegrator type, and containing within a cast-iron chamber two disks fitted with concentric rows of steel pins, one of these disks being fixed in the machine, and the other being keyed upon a shaft which revolves at a greater or less speed according to the

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nature of the material upon which the machine has to operate. The pins or pegs of the respective disks overlap one another, so that any material entering the centre of the standing disk, and driven thence to the periphery by the centrifugal force exerted by the running disk, must pass between the several rows of pins. These machines are made in two forms, one being the so-called "single dismembrator," and the other the "double dismembrator." The difference between the two consists in the former machine containing two disks, as described above, whilst the latter has two fixed disks, and a movable or revolving one working between them, the central disk being fitted with pins on each side, which overlap those of the standing disk, thus forming, as it were, two distinct machines within one case. No communication being held between the two sides, two different assortments, as for instance, wheat and bran, or middlings and tailings, may be operated upon at one and the same time without the separate products coming into contact with one another in any way. Their "dismembrator" runs at three thousand revolutions per minute.

(3.) *Centrifugal dressing machines.*—Within a horizontal and slowly revolving cylindrical frame, covered with perforated zinc, wire or silk gauze, is a revolving shaft fitted with curved beaters, which throw the material against the covering of the cylinder, thereby effecting the required separation of flour, middlings and offals.

(4.) *Purifiers for middlings.*—The wheat after being cleaned is, according to the most improved method, passed between fluted rolls, with a view to opening the crease of the wheat and enabling the blue flour and dust to be separated from the grain before the actual reduction of the latter commences on the smooth rolls. The separation of the blue flour being accomplished, the wheat passes directly to the first smooth roller-mill, where it is simply crushed, and passes directly afterwards to a dismembrator, where the crushed particles become separated from one another by the action of the pins or pegs.

Hence they go to the dressing machines, and are separated into flour, middlings, and offals, the great bulk of the latter being discharged in the form of heavy bran. The heavy bran passes directly to its own smooth roller-mill, whence, after being crushed, it enters a dismembrator below, and after passing through a filter, finds its way to a second set of dressing machines. The bran is discharged from these machines in a completely finished condition, as also a small percentage of flour.

The middlings which have been produced by the above opera-

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tions are sized and purified, and pass to their own rollers, dismembrators, and dressing machines. The tailings from this process, or such of them as may be of value, are again purified, and pass to their own roller-mill, dismembrator, and dressing machines, and thus the reduction of the grain is completed.

The use of smooth rollers without differential speed seems a mistake, for their action necessarily consolidates the flour into flakes, and the mechanical work spent on this has to be undone again by the mechanical work of the dismembrator.

Advantages of Roller-mills over Stones.

The principal advantage of roller-milling is that the bran or husk, and the germ of the grain, are flattened out by the action of rolling, and can consequently easily be sifted out by proper application of dressing machinery. This advantage cannot be over-estimated, seeing the detrimental action which both bran and germ have on the keeping and baking qualities of flour. Where the oily germ is ground up with the semolina, the flour easily gets musty when kept. Such flour is therefore totally unfit for export.

It is stated that from the germ contained in 1 cwt. of wheat nearly 1 lb. of oil can be extracted. As to the removal of this deleterious body, Professor Kick stated, in 1871, in his work on the manufacture of flour, that during the grinding process there are obtained certain classes of middlings containing from 30 to 40 per cent. of germ. If one lets such middlings pass through rollers set to the proper distance, these tough germs are only flattened whilst the middlings are crushed, and it is then easy to remove them by dressing machinery.

Of course, this oily or fatty substance is of considerable value as an article of food, but it should for the reason stated not be eaten by man, but after being separated from the grain, be sold for cattle, and this is now done by many millers either separately or in the bran. Although the removal of the germ is innate and inseparable from the use of roller-mills combined with dressing machinery, it has nevertheless, many years after the above quotation from Professor Kick's book, been made the subject of a patent in this country, and this question is at present exciting considerable interest, and has been taken up by the National Association of British and Irish Millers.

The rough and extended surfaces of the stones necessarily attack the husk and germ of the grain during its passage much more

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than it can possibly be attacked by the merely momentary contact of the smooth surfaces of the rollers. The action of the rollers resembles a squeeze, unlike the more protracted rubbing action which the grain undergoes during the passage between and across the faces of the stones, and which detaches from the outside of the grain an infinite number of small particles of bran. These, after once having got into the flour can, in no possible way, be got out again. On the other hand roller-mills flatten the germ and even very small particles of bran, and render them all the easier to dress out by the following operation. This is one of the principal reasons why flour produced by good roller-mills is so much whiter than that ordinarily produced from the same wheat by stones. Furthermore the longer treatment or friction or pressure between stones increases the heat, even in high grinding by stones, to a much greater degree than in high grinding by rollers. For these reasons no rough surface of any kind should be used for the grinding of middlings, for to one of their sides a part of the husk of the grain almost always adheres, which in regrinding between rough surfaces is attacked simultaneously with the floury parts and more or less rasped to pieces. It is this consideration which lies at the bottom of the fact that even porcelain rollers are getting out of fashion and are no longer used in Budapest, the porcelain surface standing as it were somewhere between the millstone and the smooth chilled-iron surface of the present roller-mill.

In the old stone mill a serious expense was occasioned by the necessity of redressing the surface of the stones. This is necessary, say every ten to fifteen days, when at work day and night. The expense for performing this operation is stated to be about £15 per annum per pair of stones.

The artisans doing this kind of work are highly paid men. So important is this expense that one of the most extensive practical millers of this country, in conversation with the Author, maintained that, in the case of a firm with sufficient capital, the replacing of his whole old-fashioned stone-mill machinery by a modern roller-mill plant might be considered to cost nothing, for the expense saved in stone-dressing is sufficient to pay interest on the capital required for the operation. This seeming paradox tallies very nearly with the facts ascertained in several mills built by the Author, the total cost of which, including erection, amounted to £2,500 sterling, and the saving in stone-dressing being said by the owners to amount to about £2 10*s.* per week, being at the rate of about 5 per cent. interest on the capital

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invested. But this circumstance is almost insignificant in comparison with the otherwise largely improved results in the quality of the flour produced by a sound roller-milling system. The following Table taken from actual work in one of the mills constructed by the Author will serve to prove this assertion. It shows reports of four different grists, three of them by roller-mills and one by stones, the latter obtained in the same mill before it was altered by the Author. It may be added that the mill in question was considered one of the best conducted stone mills in Ireland. The three roller-mill grists were likewise obtained in the ordinary course of business, and not with any special care. The stone-mill grist is one of the best ever obtained. A comparison, therefore under such conditions between the two classes will be less favourable to the roller-mills than if compared with stone-flour from ordinary average mills. Nevertheless, it will be noticed that the amount of money realised by the roller system in grist No. 1 amounts to £73 16*s.* 6*d.* as against £66 14*s.* 6*d.* in the case of grist No. 4 of the stone-mill; that is an extra profit of £7 2*s.* in the conversion of 100 cwt. of wheat into flour. In the case of grist No. 2 the extra profit is £7 12*s.*, in the case of No. 3 £8 10*s.* The average therefore is equal to £7 15*s.* extra profit in every 5 tons of wheat ground, or 5*s.* on every sack of flour produced by the Author's system.[1]

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[1] 1.—*Roller-Mill.*

8,317½ cwt. uncleaned wheat, consisting of

2,165	cwt.	No. 2 Spring.
1,812½	„	White Australian.
750	„	Taganrog.
750	„	Red Winter.
2,840	„	Irish.

				£.	s.	d.	£.	s.	d.
No. 00 Patent	8½	per cent.,	at	1	1	0	8	18	6
„ 0 Patent	14	„	„	0	19	6	13	13	0
„ I.	40	„	„	0	18	0	36	0	0
„ II.	6	„	„	0	15	6	4	13	0
Inferiors	4	„	„	0	11	6	2	6	0
Bran	10	„	„	0	6	0	3	0	0
Pollard	16	„	„	0	6	6	5	4	0
Tailings (wheat)	½	„	„	0	4	0	0	2	0
Waste	1	„	„		..			..	
	100 cwt.						£73	16	6

This is the ordinary work for two months without any special attention.

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What this means will be understood when it is borne in mind that from 1*s.* to 2*s.* is said to be an ordinary average profit per sack of flour.

With regard to manual labour a considerable saving is effected by the roller-mill system if worked automatically. All that in such cases is requisite is men to watch the equal feed of the rollers, and to take off the finished products at the end. A roller-mill on the automatic system, with a capacity of, say, 40 cwt. of wheat per hour, should take no more than two or three men to

2.—*Roller-Mill.*

Trial of 250 cwt. Uncleaned Western Winter, and 125 cwt. Uncleaned Irish.

			£.	s.	d.	£.	s.	d.
No. 00 Patent	4	per cent., at	1	1	0	4	4	0
„ I.	63	„ „	0	18	6	58	5	6
„ II.	3	„ „	0	15	6	2	6	6
Inferiors	2	„ „	0	11	6	1	3	0
Bran	10	„ „	0	6	0	3	0	0
Pollard	15	„ „	0	6	6	4	17	6
Tailings (wheat)	3	„ „	0	4	0	0	12	0
	100	cwt.				£74	8	6

Ground in the ordinary course of the mill, with special attention at the rolls.

3.—*Roller-Mill.*

Trial of 250 cwt. Cleaned Southern Winter Wheat (straight run).

			£.	s.	d.	£.	s.	d.
Prime flour "straight"	70	per cent., at	0	18	6	64	15	0
Inferiors	4	„ „	0	11	6	2	6	0
Bran	11	„ „	0	6	0	3	6	0
Pollard	15	„ „	0	6	6	4	17	6
	100	cwt.				£75	4	6

Ground with very special care and carefully re-purified.

The 70 per cent. prime flour was baked with and found fully equal to a brand which is considered the best stone-mill flour in the United Kingdom.

4.—*Stone-Mill.*

Trial of 375 cwt. of Prime No. 1 Spring Wheat, uncleaned.

			£.	s.	d.	£.	s.	d.
No. I.	60	per cent., at	0	16	6	49	10	0
„ II.	9	„ „	0	15	6	6	19	6
Inferiors	4	„ „	0	11	6	2	6	0
Bran	15	„ „	0	6	0	4	10	0
Pollard	10	„ „	0	6	6	3	5	0
Waste	1	„ „		..			..	
Tailings (wheat)	1	„ „	0	4	0	0	4	0
	100	cwt.				£66	14	6

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work it. A stone-mill of corresponding size would require four or five men, besides the stone-dresser.

As to non-automatic roller-mills the Author has the authority of a miller, intimately acquainted with the best English and Irish milling processes, who considers that there is no saving of hand-labour in such a mill as compared with first-class stone-mills producing the best quality of flour. His opinion is that the great advantage of roller-mills lies in the superior quality and value of the flour, as compared with these qualities produced in ordinary, or even first-class, stone-mills from the same materials.[1]

A further advantage of roller-mills over stone-mills lies in the fact that they are much less liable to disastrous explosions and consequent destruction of life and property than stone-mills. Any pair of stones running empty is liable to strike sparks, and if the air surrounding the stone is laden with very fine and impalpable flour dust, as is mostly the case, an explosion is almost certain to follow, and to extend sometimes to very great distances through the connections of the different machines, and into the stive room. Any empty running roller-mill, however, is not likely to strike sparks, and the principal cause of the explosions and conflagrations is thus removed. That this is so is supported by the fact that fire insurance companies are already making material reductions in their rates in case of mills using a pure roller-mill system, *i.e.*, no stones whatever, and having all their wheat-cleaning machinery outside the mill. Roller-mills, moreover, require much less space than stone-mills, and this in most cases is of great importance, especially in English towns. It may be said that a building containing a good average stone-mill plant, as heretofore in use, can be made to turn out from one-and-a-half to double the quantity of flour by a well-considered roller-mill plant.

Power required.

Mr. Otto Mueller, of Budapest, a first-class authority on, and constructor of, steam engines, states that in Hungarian roller-mills the quantity of wheat ground per indicated HP. per day of twenty-four hours, varies from about 2·7 to 5·5 cwt.; also that with stones the quantity of wheat was equal to 3·15 cwt.

Roller-mills therefore show an output of from about minus 19 to plus 75 per cent., that is a larger average output, and this notwith-

[1] A recent article on "The Flour Mills of Minneapolis," in *The Times* of February 3rd, 1882, corroborates this on the authority of Governor Washburn, who declares "that he can produce as fine flour from No. 3 or 4 wheats as was formerly obtained from No. 1 or 2."

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standing the fact of there being in Budapest a great many old-fashioned roller-mills in use, in which nothing has been done for relieving and reducing pressure and friction. In the modified or simplified roller process of the Author, the dressing machines are much improved on what exists in the old mills in Budapest, besides their number being considerably reduced. The power therefore required per cwt. of wheat ground is considerably less.

In a mill erected by the Author at Tadcaster near Leeds, and capable of grinding 15 cwt. of wheat per hour, the turbine driving the machinery was measured to exert 30·17 HP. with full water. This gives about ½ cwt. of wheat ground per hour for each indicated HP.

A complete roller-mill plant of the same size has been erected for Mr. Ashby of Croydon, and is driven by steam. Mr. Ashby gives the HP. consumed as 50, including, however, one pair of stones or, say, 3 HP. per cwt. of wheat ground per hour. In a similar mill, which belongs to the Messrs. Shackleton, at Carlow in Ireland, driven by water, the HP. is equal to 35 to 40. The increase in power in this latter mill is explained by a less favourable and more roundabout way of transmitting the power from the old wheel to the new machinery, and in the case of the mill at Croydon by the fact of a pair of stones being included. Nevertheless these results confirm each other fairly considering the comparatively small size of the mills.

These three together would therefore give an average of, in round numbers, 2½ HP. per cwt. of wheat ground, or, say, 45 lbs. per HP., which, compared with the Hungarian results, shows a great difference in favour of the roller-mill system used by the Author. This is easily explained by the reasons stated above, and by the special construction of the three-high roller-mill used in this system in which friction is to a great extent successfully overcome, also by the reduced number and improved construction of centrifugal dressing machines employed, which consume less power than the immense number of old-fashioned long silk-reels still in use in Hungary.[1]

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[1] Recent trials with the indicator made in two roller-mills established on Mr. Simon's system, and grinding about 50 cwt. of wheat per hour, confirm the fact that 1 HP. per hour will grind nearly ¼ cwt. of wheat. In one of the mills in question, recently altered from stone-milling to Simon's roller-milling system, while the quantity of flour under the old system was between eight and nine sacks per hour, it has increased to eleven to twelve sacks per hour, the quality being of course superior. At the same time the weekly coal bill has been reduced by about £1 sterling.

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Introduction of Roller-milling in England.

One of the first to attempt the introduction of roller-milling on a large scale in England was Mr. G. A. Buchholz, the inventor of a considerable number of machines for decorticating or hulling, and grinding flour. Messrs. J. Fison and Co. of Ipswich, introduced Mr. Buchholz's first mode of semolina grinding in 1862. They report that it was worked for a few years and then given up entirely, excepting a hulling-machine which is still used occasionally for cleaning wheat. Mr. J. Stannard of Nayland, near Colchester, commenced working Buchholz's system in 1871, and ceased doing so in 1872, discarding all the machinery of the plant except two smooth roller-mills which he used for semolina after it had once been ground by stones. The reason for this seems to have been that the mode of adjusting the rolls was imperfect. There were six pairs of rolls in one frame about 6 feet high. The flour was not regular in quality. The bran chopped up and was not liked by the farmers.

Mr. Stannard got about 30 per cent. of superior flour from fine red wheat, which sold in London at 2*s.* to 3*s.* per quarter under the finest Hungarian. He also made some intermediate flour, and fully 20 per cent. of bran flour, for which at that time no market existed either in Colchester or London. The bran flour was made by stones. Messrs. Baker Brothers of Bristol erected a somewhat similar plant.[1] Attempts with similar, or worse, results were also made at Liverpool, Glasgow, Cork, and one or two other places. These entire or partial failures created no small prejudice amongst millers in this country, and delayed the introduction of improved machinery which began to be offered by milling engineers a few years later.

Mr. Oexle introduced the Hungarian milling process in 1868 in the North Shore Mills, Liverpool, and somewhat later in the mills of Messrs. Davidson and Sons of Newcastle, along with rollers for crushing middlings. A more complete roller process was introduced by the same gentleman at the Tradestone Mills in Glasgow in 1873. The first real impetus, however, to a general use of roller-mills in this country was doubtlessly given by Mr. Wegmann's porcelain roller-mill.[2]

Until the advent of this machine the ordinary British miller

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[1] Institution of Mechanical Engineers. Proceedings, 1872, p. 225.

[2] More about the history of milling in England can be read in the "Miller" of March 5th, 1877, and following numbers.

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considered middlings as a kind of drug in the market. Great, therefore, and rapid was the success of the porcelain roller when it was shown, by its introducer, Mr. Oexle, that excellent flour could be made from middlings, the branny part being flattened out by the rollers and dressed afterwards by purifiers.

Mr. T. Richardson of Bishopwearmouth Steam Mills, Sunderland, President of the National Association of British and Irish Millers, in a Paper read in 1881, "On the Treatment of Middlings," said, "We are now getting a useful flour from stuff that used to go to the pigs, and it looks better after purifying and rolling than it did before."

The system advocated by the Author was introduced in England on an experimental scale in 1877, in the mills of Messrs. McDougall Brothers of Manchester. Its success was so decided that this firm gradually extended their roller-plant, until in the two following years rollers had entirely replaced stones. More than seventy roller-mills have been supplied to them, besides dressing and purifying machinery. Encouraged by this result the Author accepted the invitation of the Council of the National Association of British and Irish Millers, to read a Paper "On Roller-milling," at their first annual meeting in June 1879. Some of the assertions and predictions then made were considered very bold, but they have now become almost universally recognised truisms. Since that Paper was read, and since the Kilburn Exhibition of 1879, the application and development of the system has been steadily carried on, and its details perfected and adapted to the requirements of this country by practical experiments on an extensive scale. The satisfactory character of the results are best attested by the fact that the system in question has now been introduced, more or less in its entirety, into twenty-five English, Scotch and Irish mills, and that, after practical experience of these satisfactory results, several of the millers who first established such roller-mills have proved their satisfaction and confidence by duplicating, and even triplicating the plants originally erected and worked for periods varying from one to two years. Some of the millers are still using the previously-existing stones for doing part of the work; but by far the larger numbers are working exclusively with chilled-iron Daverio rollers; but several of those who began by only executing part of the process by rollers have, after seeing the superior results obtained by them, thrown out entirely the remainder of their stones. The number of secondhand millstones and appurtenances for sale in England is consequently considerable and daily increasing. Porcelain roller-mills are beginning to share

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a similar fate. In some of the mills built by the Author porcelain rollers are being put aside or sold in favour of the Daverio roller-mill with chilled iron.

The fundamental principles of this process are the following:—

First. Gradual reduction of the wheat by fluted rollers with sharp corrugations.

Secondly. Cleaning of the bran by fine fluted rollers, all with differential speed.

Thirdly. Gradual reduction of the semolina principally by smooth rollers, or in some cases by fine fluted rollers. There is little objection to use already-existing pairs of stones for the reduction of certain kinds of the cleanest and best middlings.

The best flour obtained during this process is that made by regrinding the purest middlings. The best granulation is therefore necessarily that which produces the most middlings and the least direct or break flour, that is, flour obtained unwillingly during the several granulating breaks or reductions given to the grain by the fluted rollers.

It may here be mentioned that an American inventor recently re-introduced in Europe the exploded idea of using rounded corrugations or flutings. A large number of his rolls were adopted by American millers, but many of these are being changed for rollers with sharp-covered flutes. Necessarily, a roller with rounded flutes squeezes more and produces more break flour, hence its unsuitableness for "*griesmüllerei*" or semolina grinding.

Before proceeding further, it will be necessary to describe somewhat in detail the principal machinery used in this process.

Daverio-Simon Roller-mill.

It is now usual to construct roller-mills to contain two pairs of rolls in one frame, with all four rolls arranged in a horizontal plane. These four rollers of course give two grinding surfaces. Now, the idea presented itself of using only three rollers instead of four, placing them vertically one above the other, and this idea was carried out by Mr. Daverio, of Zurich. Two grinding surfaces are thus obtained with three rollers, and consequently with six journals only instead of eight. A large saving in power by the elimination of one roller out of four is self-evident. But it is even much larger than appears at first thought, for the pressure of the top and bottom rollers being equal and exerted from opposite sides against the middle roller, it follows that the friction of the two journals of this roller is almost entirely annihilated or counterbalanced. There

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remains therefore virtually only the friction of the top and bottom journals, namely, other things being equal, the friction in good three-roller-mills is, by these circumstances, reduced to about one-half that of four-roller mills. There arose, however, a serious difficulty. It was found that no good effect is obtained by letting the grain or semolina undergo two consecutive operations in the same roller mill without intermediate purification. An apparatus had therefore to be contrived to divide the material put into the hopper to be ground into two different streams, one of which should pass between the top and centre roller, and the other between the centre and bottom roller. Several devices were tried ineffectually, until finally Mr. Daverio hit upon the idea of employing what may be called a cross-channel piece (Plate 7, Fig. 1), which allows the material ground between the top and centre rollers to fall down past the two lower rollers, and which conducts the material to be ground between the centre and bottom rollers, across or through this stream of ground material into the desired place between the two lower rollers. With the application of this device the manufacture of three-high rollers became possible and successful. But another step remained to be achieved, namely, the further reduction of friction or power consumed for driving these mills. In this respect again, it is the three-high or trio-roller-mill which bears off the palm. The contrivance employed by Messrs. Ganz and Co., who also manufacture roller-mills, consists in placing upon the shafts of the top and bottom rollers on each side of the frame a small ring on which a large strong hoop is sprung so as to embrace the two rings with the requisite pressure, while they cause the hoop to revolve by their rotation; and it is intended thus, to some extent, to relieve the friction of the bearings, but it would seem that this way of effecting the object is not of much practical use. The hoops in question, owing to their great diameter, must have an undesirable degree of elasticity, which must stand in the way of their relieving the pressure; and they are, moreover, themselves continually subjected to a regular and uninterrupted cold-rolling process, not unlike that employed by engineers for rolling, *i.e.*, lengthening, railway tires and hoops. The deterioration in a limited period of these continually cold-rolled rings cannot be doubtful, and with this their usefulness of course decreased. In the Daverio mill this problem is solved in an entirely different way. It carries the journals of the upper and lower rollers in bearings A A (Plate 7, Fig. 5), forming part of the bell-crank levers B B, which have their fulcrums at C C. The pressure of the swing-rollers in these bearings is taken up by the friction-rollers D D, and transferred

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to the small pins E E, upon which they revolve. Supposing, for instance, the diameter of the rollers D D to be six times as large as the diameter of the pins E E, then the power required to overcome the frictional resistance between the said roller and its pin will be only one-sixth part of the power that would otherwise be necessary for overcoming the friction between the journal and its brasses. The brasses shown in the sectional view serve principally to prevent lateral play of the journals, and are cut away to allow the friction rollers to come in contact with the journals. This arrangement therefore further reduces the friction very considerably, and this explains the low amount of power required for driving Daverio mills. This arrangement has other great practical advantages. The centre roller is fixed by set screws, once for all at the works. The necessary motion in the vertical sense of the top and bottom rollers, both for setting them horizontal and regulating their pressure on the centre roller, is achieved by means of the two springs, T T, and the hand-wheels U U. The lever V, serves for instantaneously increasing the distance between the rollers by simply putting it down, and thus the difficulty in starting often experienced in other roller-mills, owing to a wedge of material having formed between the rolls, is perfectly and easily overcome. This lever is an advantage possessed by the Daverio mill over others. By it the distance between the rolls can be altered whilst the mill is working without taking the pressure off; thus the pressure is independent of a regular feed, and an irregularly distributed feed does not affect the position of the rolls; whereas, in other mills, if less feed goes in on one side the rolls close in and touch on that side, wear irregularly, and give an irregular product. Any sudden cessation of feed causes a shock to the rolls, which this hand-lever entirely prevents.

The friction rollers are almost as important on account of the services they render in lubricating the journals as in reducing the friction. They oil the journals continuously and self-actingly, and running in closed boxes, a great saving in oil results. Where the friction roller is above the journal others are provided below it to do the lubrication. This saves power, besides ensuring immunity from hot bearings, and less care and attention are necessary in working. Another advantage of the three-high roller-mills is the much smaller floor-space required in comparison to all others. One of these mills, for instance, occupies an area of only 32 by 20 inches, and its small weight, 18 cwt., moreover, allows of its being placed on any floor, even in lofty buildings of light construction.

For the reduction of semolina into flour, roller-mills composed of

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smooth rollers are employed, but other rollers are necessary when it is desired to carry out the whole grinding process by rollers exclusively. In that case it is necessary at certain stages of the process to use fluted rollers of different degrees of fineness. The section of rollers ordinarily used for this purpose is shown in Plate 7, Fig. 3, and differential speed must be employed. The grooves or flutings are put on with a twist like the grooves in a gun. Rifled rollers might therefore be an appropriate name for them. The effect of the twist is that the grooves of one roller cannot catch within those of the other, even when close together, but those of the quicker speeded roller continually overtake those of the other one, producing an action which would be a kind of shearing if the rollers really touched each other; but this not being the case, it really consists in twisting the parts of the grain against each other, the sharp corners of the flutings holding the outside of the grain fast, and, as it were, pushing the opposite sides of each grain in opposite directions, thus opening them and disintegrating their contents. Such rifled rollers last for years without sharpening or grinding.

Dressing-Machinery.

The ordinary silk dressing-reels may, of course, be used in connection with roller-mills, as they still are almost everywhere in the United States, where only lately has the use of the so-called "centrifugals" spread to some extent. In England the introduction of centrifugal dressing-machines during the last few years marched abreast with the introduction of roller-mills. Plate 7, Fig. 2, shows the section of one class of these machines, as used in the Author's roller-milling system.

This is called a combined wire and silk centrifugal. The principal part of all centrifugals consists of a slowly rotating cylinder silk, inside which a number of wings or beaters rotate in the same direction, but at a quicker rate. The object of these inner beaters is to raise the material let into the machine, and throw it, in a gentle cloud, as evenly as possible, all over the surface of the outer cylinder. By rotating the outer silk cylinder a fresh surface is continually presented to the material thrown by the beaters, and this ensures more equal wear and tear of the silk. The great advantages of the centrifugal machines over the ordinary cylinders of silk consist in their turning out a much larger quantity of improved work, and in taking less space than the ordinary slow-going silk reel heretofore in use. The action of the beaters is, moreover, very useful in cases where the material, having passed through the

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roller-mill, has become flaky or caked. It is then disintegrated before touching the silk, and consequently passes through more easily. In dressing branny material, the action of the beaters is again useful in detaching many parts from the bran, which, in an ordinary dressing-cylinder, would remain adhering to it. The more energetic action of the centrifugals permits of finer silks being used, and the flour is therefore whiter and freer from impurities. With the ordinary silk reel, the numbers of silk used are from No. 9 Swiss silk to No. 13, or one hundred to one hundred and thirty-four meshes per inch. In very few instances are finer numbers used upon reels. With the centrifugal, on the other hand, the numbers vary from No. 12 to No. 16, or even No. 17 Swiss silk, that is, from one hundred and twenty-four to one hundred and seventy meshes per inch, and only in using damp English wheat, the flour from which is softer and more difficult to dress, is it necessary to use, upon some of the centrifugals, silks as coarse as No. 9, or one hundred meshes per inch.

Much depends upon the dimensions given to the machines, and upon the shape, size, and position of the inside beaters. A great many centrifugals create wind-pressure, which interferes with the dressing, and is not desirable for other reasons. Others throw the flour against the silk in lumps, and large quantities at the same time. In most centrifugals the inner beaters are put on helically, and by their rotation transport the flour, during the dressing process, from the inlet of the machine at one end towards the outlet at the other end. Numberless are the patents for different shapes and positions of these beaters. A great many beaters are solid blades of wood or iron. In the machines used by the Author, the beaters are parallel to the axis of the machine, and cut into a series of narrow radial fingers or blades, each of which has a skew twist at the end.

The advantages of this arrangement are that these beaters oppose less surface to the air, which to some extent can pass between the different finger-like blades; consequently less wind-pressure is created than in the other centrifugals. Furthermore, each single finger-blade throws the flour in smaller quantities at a time, and in a more gentle and cloudlike way, towards the outer dressing cylinder.

This apparatus is generally enclosed in a wooden box, which, in its lower part, is divided into compartments. The dressing silk on the outer cylinder is composed of two, three, or four different pieces of silk of different fineness, each of which may dress into one compartment. In many cases, at the bottom of the box a

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worm is placed, for transporting the flour out of the machine. Sometimes it is advantageous to put two worms, one over the other, separated by a partition with slides, so that, according to the different products obtained from different classes of wheat, by the opening or closing of a slide at a convenient point, one part of the product may be drawn to the left, the other to the right, and thus separated and drawn into different classes of flour. A centrifugal dressing-machine, which by its construction produces a tangible amount of wind-pressure, injures the quality of the flour by pressing branny particles through the silk, as small particles of bran in that case may be forced through the silk along with the flour. The particular construction of the beaters here described allows of their being driven with safety at a comparatively high speed. Good numbers of revolution are two hundred to two hundred and fifty for the beaters, and about twenty for the outer cylinder. At the same time, the number of such beaters may be small; it varies in the machines used by the Author from three to eight.

Such machines, under 80 inches in length, dress better than the usual old-fashioned plain reel of three times that length, and no more power is required.

Each machine is driven by one belt only. In order to prevent the excessive wear of silk, the construction of the machine is specially adapted to suit the different classes of material. They are made of the following kinds:—

1. All silk flour-dressing-machine.
2. All wire scalping-machine, single and double.
3. Combined wire and silk dressing-machine.
4. Double machine, wire above and silk below (Plate 7, Fig. 6).

Each of these different kinds of machine is made in two or more sizes, the larger size only about 2 feet 6 inches in diameter, the smaller size about 1 foot 8 inches in diameter, and of a length proportional to the class of work and material. Great prejudices exist against machines of such small diameter, and many makers produce enormous space-wasting machinery, which, however, presents no advantages of any kind, the machine here described doing the best possible class of work, both as respects quality and quantity.

The wear and tear of the silk used in flour mills is a costly item, principally so in centrifugal dressing-machines, which do their work more vigorously than the old reel. A special strong silk is therefore generally used. It is important to keep the coarse sharps or bran away from the silk, otherwise the latter is quickly worn out. Hence it is usual in Hungary, and some other countries,

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to have a special wire machine before each silk centrifugal, to take these sharp parts out, but this is costly in money and space.

This difficulty is met by the machine shown in Plate 7, Fig. 2, which is called a "combined machine." The part on the left is covered with perforated metal or wire cloth, which throws off the bran and coarse sharps, and only allows the flour or fine middlings to pass into the silk or second part on the right-hand side. Thus the hard part of the work is taken off the dressing silk, which consequently lasts much longer. Plate 7, Fig. 6, shows a section of double centrifugals used in larger mills, the top reel being clothed with wire, the bottom reel with silk; they are placed one on the top of the other, to save floor-space and to avoid the necessity of elevating the material again from the one into the other. But few old-fashioned mills have floors of sufficient height for allowing ordinary centrifugals to be placed one above the other. To meet this difficulty, the material dressed through the top cylinder is lightly scraped along the concentric bottom part of the top machine, by leather or rubber scrapers, on to the worm W, which transports it to one end and into the lower silk machine. This arrangement enables the two dressing-cylinders to lie almost close together, and a double machine, of a height of only 7 feet 6 inches, is thus obtained.

Purifying-Machinery.

Middlings and semolina, coming from the cracking or break-rolls, are to a great extent mixed with particles of bran and flour; it is necessary to separate these from each other, as the best results in high grinding can only be obtained by the further reduction of the cleanest possible middlings. In the purifier used by the Author, the middlings to be purified are graded into about four different sizes by a shaking sieve placed along the top of the machine, and going at the rate of four hundred or five hundred vibrations per minute. Each grade falls directly through a blast of air produced by the suction of a fan placed in the machine itself (Plate 7, Fig 7). Each half of the machine produces two grades only. The grading is entirely separate in its action from the purifying. The middlings fall from the silk sieves, at the points marked A A, into the purifier proper, and along ledges of wood, at F F. Slides exist to regulate the suction. In order to further regulate the direction of the purifying air-stream sucked into the machine, and through the stream of middlings falling down, regulating flaps (D D) turn round the points E E.

The stream of air enters the opening and passes through the

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middlings, the heaviest particles of semolina falling straight down. The lighter are carried over the movable blades, and fall into the next compartment, and the lightest and branny particles are carried through into the third compartment. In order to avoid the possibility of any loss through good material being carried by the blast into the stive chamber, the pressure of wind employed is very slight, but the middlings are caused to pass from three to five times through the blast, so that every grain is, so to speak, weighed and separated several times, according to its size and gravity. Each grade of middlings is divided into three or four sorts, the first being more or less pure middlings, whereas the last separations are already offal.

There are no moving parts about such a machine except the fans and oscillating grading sieve. None of the internal portions of the purifiers are liable to get out of order. The extent of the purification is under the control of the miller, and the first sorts of each grade of middlings can be made as pure as may be desired.

These machines are made in four sizes. Machines Nos. I. and I.A purify each four grades of semolina simultaneously, and make sixteen separations. Machines Nos. II. and III. purify each two grades of middlings, and make eight separations. The HP. required for any one of these machines does not exceed ½.

Description of a Modern Roller-mill high-grinding Process.

To carry out the principles and obtain the results and advantages already mentioned, the grinding of the grain by the roller-mill process is divided into three main operations. First, the granulation or separation of the outer husk or bran of the grain from the kernel; secondly, the purification of the broken kernel or semolina obtained by granulation from such portions of the bran as have become mixed with it; and thirdly, the gradual reduction of the purified semolina into flour.

The granulation of the wheat is by far the most important part of the science of milling grain, and the first and main object of the high-grinding process with roller-mills is to separate the kernel from the husk by successive gradual reductions of the grain, so as to obtain the kernel in the form of semolina or small granular particles mixed with as little flour and as little bran as possible. This granulation is best performed in the following manner:—

The wheat enters first a set of cracking-rolls which are set some distance apart, and may be, according to the nature of the wheat mostly to be ground in the mill, either plain or provided with

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coarse flutes. The number of flutes in this case is about ten per inch.

This cracking process is a continuation of the wheat cleaning, and should be kept separate, as the dust created by it can only have a prejudicial effect on the further operations. The grains of wheat in their passage to and between the rollers in this cracking-mill, rub against each other and the rolls, and are opened out at the crease, thus letting much of the dirt, which lodges there and on the surface, fall away, and, what is equally important, the slight squeeze given by the rollers unseats the germ and removes it to some extent either at once or in the scalping cylinder or centrifugal wire reel which follows this operation. The product from cracking germs and dirty flour is usually ¼ to 1 per cent. of the wheat, and can to some extent be regulated at will.

In mills of sufficient capacity to require several roller-mills for the first break, and where mixtures of wheat of very different sized grains are used, it is found advantageous to grade the wheat according to its size into two or three grades both in the cleaning and cracking processes. This enables the miller to set the first break-rollers so accurately as to perform more work in the best possible manner, just slightly cracking or opening out a very large proportion of the grains, thus releasing the dirt contained in the crease with as little good flour or semolina as possible.

This cracking process is also very useful in conjunction with and before stone-grinding. It squeezes and opens out the grains without flattening them too much or breaking the bran to any appreciable extent, thus preparing the wheat for the succeeding operations.

A miller employing stones introducing this operation may considerably improve his otherwise low-grinding results by the addition of one roller-mill with the necessary dressing-machine, which will keep out the small but harmful percentage of dirty flour. Many millers using stones have availed themselves of this facility, and this is the first step of a useful combination of existing stone-milling with roller-milling, which can be carried further at other points of the process to be described.

The further reduction of the wheat is then performed by successive breaks with sharp fluted rollers, each finer than the preceding one, and the last being a very fine fluted "bran-cleaning" mill. The number of breaks vary. Five or six breaks are usual in this country, but on the Continent many millers find it to their advantage to use up to nine breaks, as to a certain degree the more gradual the reduction the greater the advantages obtained. An

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increased number of breaks requires, of course, increased space, increased outlay in machinery, and increased watchfulness and attendance. In low grinding by rollers two or three breaks only are used.

The broken wheat, after passing each roller-mill, goes through special centrifugal scalping-machines similar to the all-silk machine. Most of these machines are covered either with perforated zinc, iron, or sheet metal, or, better still, with brass or iron-wire cloth.

Quite recently, nickel-plated wire has been rapidly introduced; it is much less subject to corrosion, although dearer; its use, therefore, in the corrosive atmosphere of manufacturing towns is to be recommended. These scalping-reels remove the semolina and flour produced at each break, and the residue of unreduced wheat or heavy bran is passed on to the next mill.

The product of the first break is separated and finished in one machine; namely, in one of the combined wire and silk centrifugals (Plate 7, Fig. 2). The wheat from the cracking-roller is delivered by the central worm to the rear end of the wire part, driven by the beaters back over the wire and passes out again at the front of the machine on its way to the second break-rollers; whereas the germs and dirty flour which pass through the wire are conveyed on into the silk cylinder in which the dirty flour is separated from the germ and small quantity of useful semolina with which it is mixed.

The products of the second, third and fourth breaks, being of about equal value, may be reduced together, and pass for this purpose into a double centrifugal with wire and silk cylinders.

The top or wire cylinder dresses out the flour and fine middlings, which are wormed together and delivered into the silk cylinder below for further separation. The coarse semolina and branny particles pass over the tail of the wire cylinder. The small amount of break-flour produced is dressed through the silk cylinder; the last operation of the silk also separates the fine middlings sufficiently pure for rolling without being first purified; and the fine semolina goes over the tail. The wire cylinder is only used because the rough semolina would wear out the silk, and all the semolina, both from the wire and from the silk, is simultaneously conveyed into simple grading cylinders to be graded or sorted into convenient sizes for the different purifiers. The product of the fifth break is dressed in a separate machine, the flour from which, being somewhat darker in colour but richer in gluten, joins the flour of the other breaks. The fine middlings and semolina produced by

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this break are small in quantity, and so much mixed with fine bran that it is more advantageous to obtain them separately and introduce them into the later operations, at a stage when the best semolina has been so far robbed of its best flour as to be about their equal in quality.

A miller employing stones may also borrow the fifth break, or bran cleaning operation, to improve his results by the partial use of roller-milling. He is thus enabled to grind higher with the stones, to produce more semolina, and to leave the work of scraping or cleaning of the bran to a separate roller-mill.

The purification of the graded semolina is performed by the machines shown (Plate 7, Fig. 7), and consists simply in causing each grade of semolina to pass several times through an air-current or suction draught, regulated according to the weight of each grade of semolina, so as to draw away all the light particles of bran or chaff which are mixed with it. To do this effectually a blast is used sufficiently strong not only to remove all light material through the fan, but also just to separate in the purifier the heavy semolina into two qualities, of which the first is sufficiently pure to go to the reducing and grinding-rollers, but the second quality is transferred to another purifier to be further purified before rolling.

In the same manner that the kernel of the wheat is gradually extracted by successive passages through fluted rollers, the reduction of the semolina, &c., into flour is attained by successive grindings by smooth rollers and dressings in centrifugal silk machines. In the first roller-mill the semolina is merely cracked or rolled with slight pressure, so as to flatten slightly any branny particles or germ and only reduce slightly the pure semolina, and the product of this roller is then dressed in a combined wire and silk machine, so that the flattened germ and offal are separated by the wire, and the flour and fine semolina by the silk cylinder. The starchy particles of the semolina being easiest reduced, it follows that the flour from this first reduction of semolina is of very good colour, but somewhat deficient in gluten. The fine semolina thus obtained is then passed through a grader and purifier on to a second set of rolls for further reduction, and as it is now nearly pure and the somewhat more glutinous particles are reached, the flour from this reduction and from the next following is the purest and strongest that the wheat contains. At each successive reduction besides the flour a quantity of fine middlings is produced sufficiently pure for grinding without further purifying, and after several reductions the material becomes so fine as to be

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too light for further purification by blast, and is then merely passed through successive rollers and dressing-centrifugals until all the flour has been extracted and nothing remains but the fibrous portions of the kernel, known as fine sharps. Of course the flour from the last grinding gradually becomes inferior in colour and quality, and from the last grinding a small percentage of soft dark flour is obtained. It will be evident that both the reduction of the semolina into fine middlings, too fine for purification, also the grinding of these fine middlings into flour, may be performed gradually, or may be retarded, by decreasing the amount of pressure at each rolling, just the same as the granulations may be finished in from two to nine breaks; and in fact it remains as an irrefutable principle in roller-milling that the more gradual the granulation, the greater the percentage and the better in quality the semolina; that the more gradual the reduction of the semolina, the greater the quantity and the better the quality of the fine middlings; and the more gradual the grinding of the fine middlings, the greater will be the proportion of the best qualities of flour.

No definite limit has as yet been ascertained beyond which this increased advantage of more gradual reduction does not theoretically hold good.

With regard to the percentage and the value of the flour obtained by this process, taking into account the germ which is almost entirely extracted, and the dirty flour from the wheat-cracking process (both of which products are necessarily mixed with the flour in stone-grinding), about the same percentage of flour can be produced from any given wheat as can be made by the stone upon the same wheat; for although the stone grinds up a certain portion of the bran into the flour, it at the same time mixes a similar portion of good flour with the offal so inextricably that no amount of dressing or purifying can separate them; thus the stone has no advantage even in regard to quantity of flour over a properly contrived and intelligently worked roller-system; whereas with regard to the quality and value of the flour, the advantage on the side of the roller is considerable. On the average the rollers produce from 72 to 75 per cent. of flour, about 15 to 24 per cent. being break-flour, or direct flour made during granulation, the remainder of the kernel being semolina and middlings. This break-flour, although naturally lighter in colour and possibly somewhat less glutinous than the semolina flour, is nevertheless from almost any quality of wheat almost equal in colour and quality to the straight-run flour made by stones from the same wheat. From the

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reduction and first grinding of the best semolina and fine middlings, a quantity of flour is produced which is worth from 5*s.* to 10*s.* per sack more than ordinary stone-flour, and this quantity varies from 45 to 65 per cent. of the total flour. From the remaining grindings of the fine middlings, flour is obtained which, mixed with the break-flour, will make a quality equal to the straight-run flour from stones, and comprising from 30 to 50 per cent. of the flour, leaving out about 5 per cent. of the flour made from the last grindings, and equal to the seconds produced by stones.

The style of granulation above described with successive single roller-mills for the several breaks located generally on the ground or first floor, and necessitating an elevator to each mill to carry up the break material to the corresponding scalping-machine on the top floor, and a large hopper with a feed-roller over each roller-mill, although in use in the best mills on the Continent and successfully adopted by the Author in many British mills, is nevertheless often unsuitable to existing mills in this country. These frequently do not possess the requisite number of floors, and if they do, floors only of very inadequate height. To meet this difficulty the Author has introduced, together with Mr. Heinrich Seck of Frankfurt, a new self-contained granulating-machine which reduces the wheat to flour, semolina, and finished bran, completely in one compact machine, with as many breaks and as gradually as may be desired (Plate 7, Figs. 8 and 9). This machine consists of a combination of all the rollers necessary for five or six breaks with three of the intervening dressing operations. (Fig. 1, p. 230.)

The wheat from the first or cracking-break done by the rollers marked I is scalped and dressed in a separate machine as hitherto. The broken wheat is then returned to the granulator at the top, and the second, third, fourth, and fifth breaks, with the intervening scalpings or dressings, are performed automatically and continuously in it, the meal from these dressings being collected for sorting and purifying. The order of the operations is indicated by arrows. The meal from the fifth break is dressed separately as heretofore. The principal feature of this machine is an improved centrifugal feeding apparatus, by which the broken wheat or bran is thrown between the rolls in the most regular manner, and over their whole width. This apparatus enables the compact form of this machine to be used, as otherwise much more vertical space would be occupied. In America a machine on somewhat similar lines has lately been constructed, but without the feeding arrangement, and with many drawbacks, both from the standpoint of the engineer and the miller. The want of

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such a feeding arrangement is the reason that the American machine goes through three floors, which, besides wasting space, much increases the difficulty of attending to the machine.

FIG. 1.

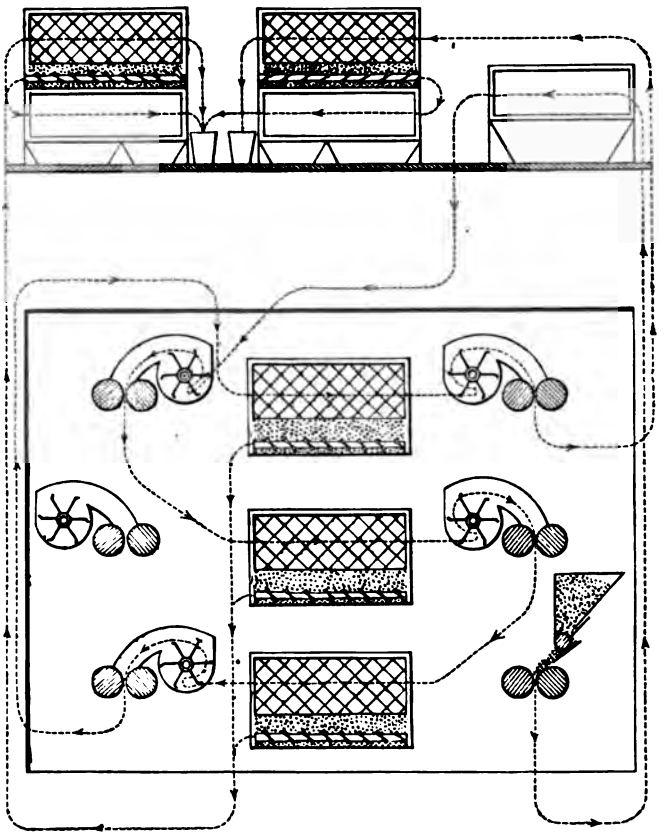

DIAGRAM OF GRANULATOR.

The centrifugal feed-apparatus is fixed on the lengthened shaft of the dressing-machine, and delivers the meal through the longitudinal opening in its casing to the next pair of rolls. The beaters are somewhat similar to those used in the centrifugal dressing-machine already described, and consist of a number of more or less radial blades J extending some distance from the axis, the surfaces of which blades are cut into finger-like sections. Each of these is so set or twisted, with a gradually increasing inclination, as to

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take up and to propel the material coming in at one end, both horizontally and radially, in such a manner as to spread it into a uniform feed, and to deliver it over the whole width of the rollers. Too much importance cannot be attached to a regular feed in roller-mills, and the Author has found in practice that the same width of roller fed by this apparatus produces considerably more work than a roller-mill fed in the ordinary way, which does not ensure the continual use of every part of the width of a roller-mill.

A general idea of the course of manufacture by the roller-process may be obtained from Fig. 2, p. 232. The wheat passes through five successive break-rollers and scalpers, the tails of the last scalper being the finished bran. These scalpers are centrifugals covered with wire-cloth to sieve out the flour and semolina produced at each break. This must be re-dressed, and it will be seen that the product from the first break is finished in a separate machine, the first half being the scalper, and the second half the re-dressing part. The product from the fifth break is also re-dressed in a separate machine as above mentioned. The product from the intermediate breaks is drawn together and re-dressed in the double wire and silk centrifugal, marked break-meal centrifugal. The product of this is break-flour or direct flour, fine middlings ready for rolling, and semolina over the tails of the two cylinders, which semolina goes to the grader, and from that to the purifiers. The purified semolina is then brought upon the first of the reducing rolls, and after rolling is dressed in a double centrifugal. The fine middlings and semolina from this first reduction go to the second reduction-rollers, the semolina tail of the silks being first purified. After the second reduction the fine middlings and again repurified tail come upon a third roller, where they are joined by the fine middlings from the break-meal centrifugal. After this the rolls may be called grinding rollers, and the subsequent operations are merely successive grindings and dressings of the fine middlings until they are finished, the tails of the last centrifugals being offal. There are some seconds and tailings from the purifiers, as also from the centrifugals, which are introduced and treated at various points in the process, so that they may be ground together with material of about equal value; but these details could not have been shown without complicating the drawing too much. The diagram represents a small roller-plant of average completeness as suitable for small mills in this country, but the reduction and grinding of the semolina would be performed more gradually, that is, with a larger number of operations, in a mill of larger size.

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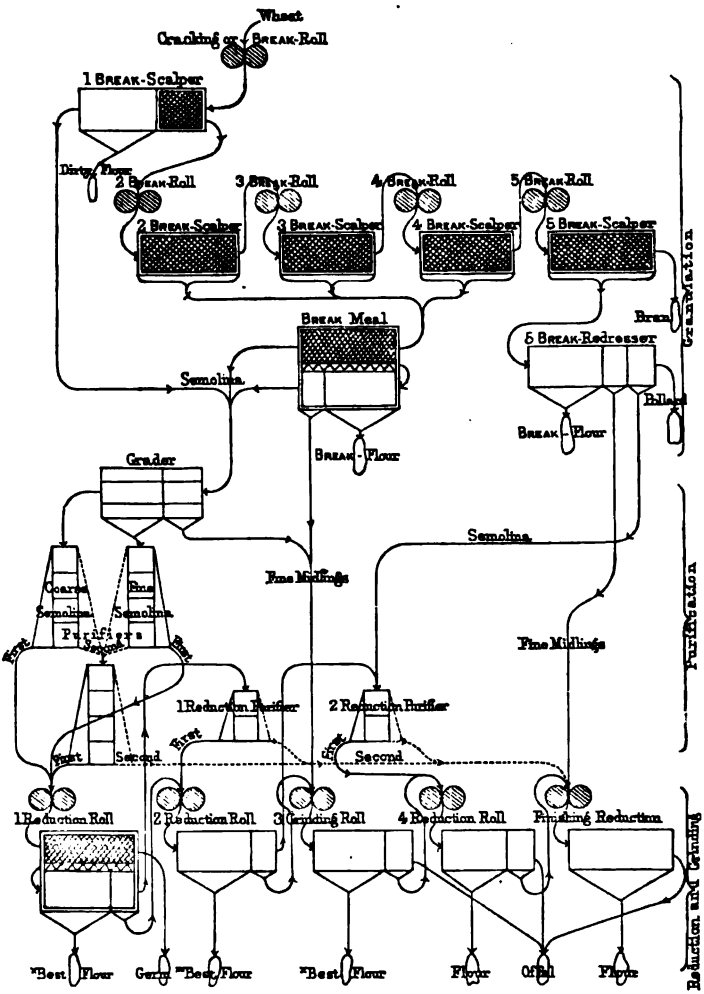
The actual arrangement of this plant in a mill-building is shown in Plate 8, from which it will be seen that the patent granulator and five reducing roller-mills stand on the first floor

FIG. 2.



along each side. Above the reducing-mills are the purifiers with worms to collect the purified semolina and convey it to the rolls, and also to convey away the offal; behind these is the grinding hopper, and on the floor above are the centrifugal

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dressing-machines; those for the break-flour and the finishing operation on the one side of the room, and those for the reducing and grinding of the best semolina and middlings on the other side. The flour from the various reductions of the semolina and fine middlings can be all drawn together to one quality or into more. The plan shows three flour-making worms so as to provide three qualities of flour, the proportions of which may be varied to suit the requirements of the millers. At the end of the building is a space divided off by a wall with double iron doors for the wheat-clearing department.

The following is a list of the machines comprised in this plant:—

Granulation—

One granulator.
One combined centrifugal for I. break.
One combined wire and silk double centrifugal for II., III., IV. break.
One double wire and silk centrifugal for V. break.

Purification—

One grader for semolina.
One purifier for coarse semolina.
One purifier for fine semolina.
One semolina repurifier.
Two small purifiers for semolina tailings.

Reducing and Grinding—

Five three-high middlings roller-mill.
Five silk centrifugals.
Two detachers.

The capacity of this plant is about six hundred sacks of flour per week. The HP. required to drive it, exclusive of wheat-cleaning, is between 30 and 40 indicated. The building is 38 feet long by 24 feet wide for the roller-mill department, and 14 feet wide by 24 feet long for the wheat-cleaning. The cost of the milling machinery, exclusive of the wheat-cleaning, is about £2,000, and the fitting up of the same would require a further outlay of from £700 to £800.

The Paper is accompanied by several drawings and diagrams from which Plates 7 and 8 and the woodcuts have been prepared.

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(*Paper No. 1877.*)

Roller-Mills, and Milling as Practised in Budapest."[1]

By WILLIAM BISHOP HARDING.

THE demand for fine pure wheaten flour, free from the admixture of the external husk and coatings of the grain, has led to a series of changes which amount to a revolution in the process of milling.

The old system of subjecting the grain to the action of a heavy revolving millstone was a rough-and-ready way enough of reducing the whole to powder, but it was fatal alike to both the quality and the colour of the product, as, after being so dealt with, the subsequent separation of the finely ground bran from the flour is a physical impossibility. To obtain, therefore, the pure wheaten flour free from the admixture of particles of the external coating of the grain, an entirely different manipulation became necessary, and, amongst other plans tried, was subjecting the grain to the action of revolving fluted rollers.

Experiments in this direction were made so far back as the early years of this century, and the roller-mill was probably first brought into practical shape and used in Switzerland about the year 1820.

In the year 1839 was founded the first roller-mill in Hungary,[2] the "Josef Walzmühle," named after the Archduke Josef, who was then Prince Palatin. This mill was designed by Mr. Fehr, a Swiss engineer, and comprised thirty-six roller-mills, with which it was intended to accomplish the whole work of reduction and grinding.

Subsequent experience, however, taught that although the roller-mills were well adapted for the process of schroting or granulating the wheat, and facilitating the elimination of the husk, &c., the latter process of reducing the schrot, or grits, or coarse middlings, to flour, could be much better performed by the ample rubbing surface of the millstone; and eight pairs of stones were subsequently added to the mill machinery. This mill afterwards passed into the hands of a company, and became known as

[1] The discussion upon this Paper was taken together with that upon the two preceding ones.

[2] This mill formed the germ of the present extensive milling industry of Budapest, the projector being Graf Szechenyi Istvan, who projected the Danube Steam Navigation Company, the erection of the iron suspension-bridge between Buda and Pest, &c.

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the "Pester Walzmühle," and under the present directorate sixty-four roller-mills and several pairs of stones were added some years since. The original rollers (manufactured in Switzerland) are still at work, however, and doing good service; they are much smaller and shorter than what are now manufactured, being only 6 inches long and 5 inches in diameter. They are driven direct from the main shaft through the medium of spur-gear, a plan now altogether abandoned for the usual belt with fast and loose pulley.

In the course of the last thirty years thirteen other large mills have been erected in Budapest; they employ an aggregate HP. of about 9,000, and are now all milling on the same principle as the Walzmühle, although several of them were originally constructed for carrying out the gradual reduction system by means of stones alone. It was found, however, in all cases that the result was inferior to that obtained with the assistance of the roller mills in the Walzmühle, and within the last ten years all have been reconstructed and roller mills added.

As the result, therefore, of about fifty years' experience in Budapest, the position and function of the roller-mill in the modern system of milling has been pretty clearly defined; namely, for the preliminary processes of granulating (*Schroting*)[1] the comparatively coarsely-grooved, chilled cast-iron rollers; for the further separating (*Auflösung*),[2] either quite smooth or finely-fluted rollers furnish the best means of dealing with wheat, when it is desired to eliminate the whole of the external coatings of the grain from the products of the meal-containing kernel.

For the later reduction of the fine middlings to the desired degree of fineness, nothing has been found to surpass the millstone.

The excellence of the roller-mill does not therefore consist in its superior grinding capacity, but in its suitability for releasing the kernel of the grain from its external husk and envelope, and permitting of the ultimate entire separation of this latter from the former. It will be seen that in the earlier operation with the rolls the production of meal is purposely avoided, their function being only to break and granulate. Although it is undoubtedly possible to finish the flour with rollers alone, it has been found better, and is now the invariable practice, in all large mills, to employ stones for this purpose. Thus, in the new system of milling the roller-mills and stones each form the complement of the other.

With regard to the desirability and economy of effecting the

[1] *Schroten*—literally to break, bruise or granulate.

[2] *Auflösung*—literally loosening or dissolution: the process consists in separating small portions of bran which may be still adhering to the fine middlings.

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complete separation of the mealy portion of wheaten grain from its external coating, although this latter undoubtedly contains a considerable amount of nutriment, still it is in such a form as not to be readily assimilated by the human system, and therefore it is better to eliminate it entirely from that portion of the produce which is intended for human food, and to appropriate it to other uses. It is an undoubted fact that the freer a sample of flour is from this extraneous matter the higher is its commercial value.

The system of milling adopted in all the large mills in Budapest has for its object the obtaining from any given quantity of grain the maximum amount of fine white flour, and the increasing demand for the article, and the commercial success which has attended the costly and laborious efforts to produce it, must be taken as a sufficient proof that the end justifies the means. From 8 to 10 per cent. more of superior flour is obtainable by this system over the best arrangements of "*Hochmüllerei*," or high grinding with stones.

Wherever this result is aimed at on a scale of any magnitude, although the manipulation may vary in detail according to local circumstances and the peculiarity of the wheat to be operated on, yet the broad principle remains the same, and necessitates five or six times granulating between fluted rollers, and the passing of the produce from each "break" through a system of sorting and dressing machines; further, from twice to four times "*Auflösung*" between either quite smooth or very finely fluted rollers, the produce being carefully sorted and dressed as before, after each operation; and lastly, the passing of the pure middlings and meal between stones, and the final dressing.

The whole manipulation is arranged so as to require a minimum of manual labour, and the passing of the various products in the required direction is arranged automatically by means of elevators and conveyors.

In a large mill the method of procedure is about as follows (Fig. 3, p. 237):—the wheat, after being thoroughly cleaned, is delivered to the first roller-mill *a*,[1] after passing through which it is conveyed into the first sorting cylinder *g*; the portion passing through the mesh of this cylinder is conveyed to the first meal-sorting cylinder *n*, and the "tailings" (or produce which is too coarse to pass through, and must therefore go out at the end) conveyed to the second roller-mill *b*.

[1] Each of these granulating mills has fluted rollers; the flutings vary in degrees of coarseness, each succeeding pair being finer than the preceding one and set closer together. The flutings are not parallel with the axis but spiral.

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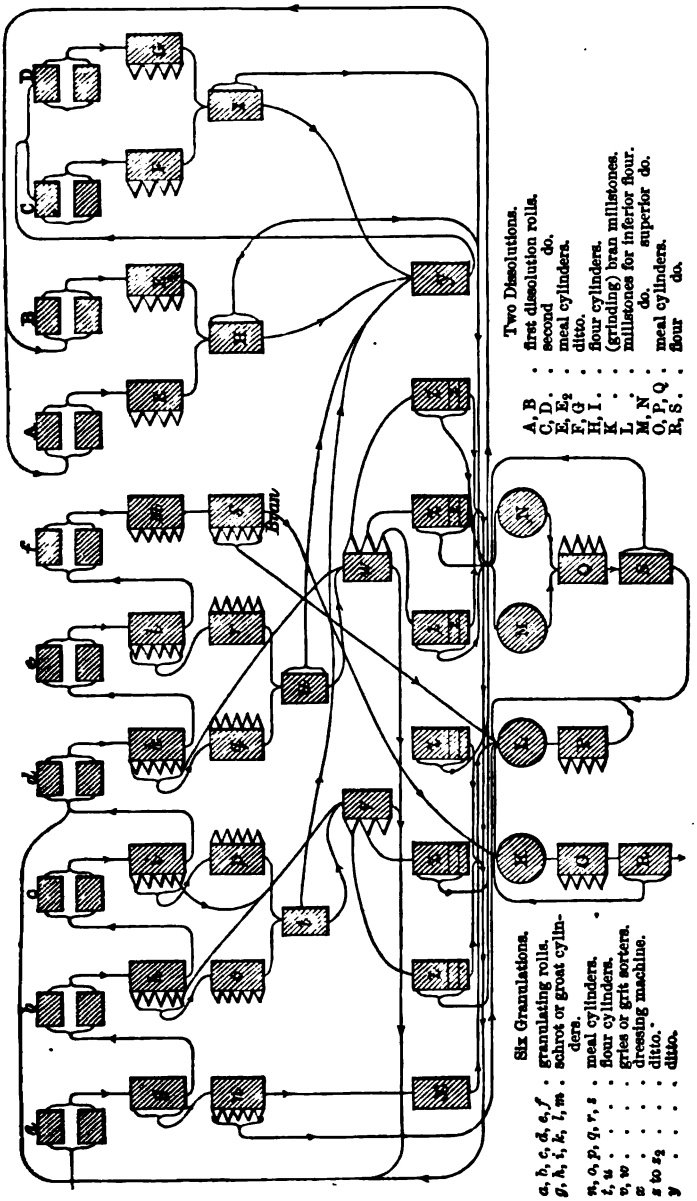
FIG. 3.—METHOD OF MILLING IN LARGE MILLS.


Bran
Six Granulations.
a, b, c, d, e, f . granulating rolls.
g, h, i, k, l, m . schrot or groat cylinders.
n, o, p, q, r, s . meal cylinders.
t, u . . . . . flour cylinders.
v, w . . . . . gries or grit sorters.
x . . . . . dressing machine.
z to z2 . . . . ditto.
y . . . . . ditto.
Two Dissolutions.
A, B . . first dissolution rolls.
C, D . . second do.
E, E2 . . meal cylinders.
F, G . . ditto.
H, I . . flour cylinders.
K . . . . (grinding) bran millstones.
L . . . . millstones for inferior flour.
M, N . . do. superior do.
O, P, Q . meal cylinders.
R, S . . flour do.

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The produce of this mill goes to the second corn-sorting[1] cylinder *h*, the portion passing through the mesh is conveyed to the second meal-sorting cylinder *o*, and the tailings to the third roller-mill *c*.

The produce of this mill goes to the third corn-sorter *i*, that portion passing through the mesh goes to the third meal-sorter *p*, and the tailings to the fourth roller mill *d*. From *d* the product passes to the fourth corn-sorter *k*, that portion passing through the mesh goes to the fourth meal-sorter *q*, and the tailings to the fifth roller-mill *e*. The produce of *e* goes to the fifth corn-sorter *l*, that portion passing through the mesh goes to the fifth meal-sorter *r*, and the tailings to the sixth roller-mill *f*. Finally, the produce of this mill is conveyed to the sixth corn-sorter *m*, that portion passing the mesh is sacked as flour; the tailings go to the bran-cylinder *s*, and that portion which passes through the mesh of this cylinder is conveyed for grinding out to the stones L. The tailings from the bran-cylinder are passed on to the stones K.

Now, following the course of the produce through the meal-sorters *n*, *o*, *p*, *q*, *r*, the portion falling through the mesh of the first partition of *n* is here caught and removed as low-grade dark flour, from the other partition, the produce is taken and ground for inferior flour by the stones L. The portion of the produce passing through the last partitions of the second, third, and fourth corn-sorters *h*, *i*, *k* are fine middlings, and pass into the middlings-sorting cylinder *v* and *w*. The produce passing through the mesh of the second meal-sorter *o* is sacked as flour, the tailings pass into the cylinders *t*, and that portion passing through the mesh of *t* is conveyed into the dressing machine *y*, the tailings from *t* go into the sorting cylinder *v*. The produce passing through the mesh of the third meal-sorter *p* is sacked as flour, and the tailings are passed into the cylinder *t*. The produce passing through the mesh of the fourth meal-sorter *q* is sacked as flour, and the tailings are conveyed into the sorting cylinder *u*. The produce passing through the mesh of *u* goes to the dressing machine *y*, and the tailings into the sorting cylinder *w*. The produce passing through the mesh of the meal-sorter *r* is sacked as flour, and the tailings are passed into the cylinder *u*; the tailings from the cylinders *v* and *w* are conveyed back to the fourth roller-mill *d*, and come again into the same course of manipulation. The "*Gries*" or grits from the sorting cylinder *v* are passed into the dressing machine *z*, and those from the sorting cylinder *w* to the dressing machine *z* 2.

[1] Corn is to be understood as the broken wheat or "schrot."

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All the various grades of fine middlings have their special dressing machines, with different sizes of mesh; these machines are, however, so connected with each other that the produce is passed to and fro until it finds the mesh which is adapted for it. The coarser-dressed middlings of the dressing machine *z* are conveyed to the smooth roller-mills A and B, the finer dressed middlings of the dressing machines *z* 2 to the millstones M and N, or in case it is desired to make a further reduction to the smooth rollers C and D.

The produce of the first smooth rollers A and B is conveyed to the dressing machines E and E 2; the portion passing through the mesh is sacked as flour, and the tailings passed on to the cylinder H. The produce escaping through the mesh of this cylinder H is conveyed to the stones M and N, and the tailings go to the dressing machine *y*, and the dressed produce from *y* to the smooth rollers C D. Thence the produce is conveyed to the dressing machines F and G, the portion passing through the mesh is sacked as flour and the tailings passed into the cylinder I. The produce passing through the mesh of cylinder I is conveyed to the stones M and N, and the tailings to the dressing machines *y*, and afterwards back again to the smooth rollers C D. The stones again have their special sorting apparatus; the produce passes from these (M and N) into the meal-sorter Q; the portion passing through the mesh is sacked as flour, and the tailings go to the meal-sorter S; the portion passing through the mesh of S goes back again to the stones M N, and the tailings to the stone L for grinding out. The product of the stone L goes to the meal-sorter P, the portion passing through the mesh is sacked as flour, and the tailings are passed again through the stones. The produce of the stone K is passed into the meal cylinder O, the portion passing through the mesh being sacked as flour, and the tailings (which are bran) being passed into the bran-cylinder R. The tailings from R are clean bran, and what passes through the mesh is conveyed to the stone L to be fully ground out.

The above method of milling is adapted for producing highly-refined flour in large quantities. In some of the mills at Budapest, however, the reduction and sorting are carried out to a still higher degree, and instead of two reductions with smooth rollers four or more are completed.

The Paper is accompanied by a diagram, from which the woodcut has been prepared.

[Discussion.

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Discussion.

Mr. Turner. Mr. E. R. TURNER had become acquainted with Mr. Buchholz soon after the opening of the International Exhibition of 1862, and introduced him to the late Mr. Joseph Fison, of Ipswich, who arranged to adopt Mr. Buchholz's system; the manufacture of the machinery for this and a number of other mills was, under Mr. Buchholz's directions, carried out by the firm of which Mr. Turner was a member. The system could, however, hardly be called one of "roller-milling," inasmuch as, at least at Mr. Fison's, only one pair of rolls was employed. These were of steel, 9 inches in diameter, grooved helically both right- and left-handed, with a pitch of about 15 inches, thus forming teeth of a prismatic form, much like those of a coarse-cut file. The first operation was that of hulling the wheat by a machine consisting of a number of drums on a vertical shaft, armed with blades of thin steel; these drums, revolving against fixed disks and concave rings similarly armed, almost entirely divested the corn of its outer coating. The wheat was then passed to the rolls already described, by which it was reduced to particles, but without being crushed. It was then sifted, and passed through a succession of small stone-mills about 24 inches in diameter, the top-stones of which were fixed, and the lower stones fast upon the revolving spindle; each of these breaks was followed by a screening; the ultimate resulting semolina was dressed through hexagonal revolving screens covered with wire-cloth. The semolina was then ground by the ordinary 4-feet stones of the mill, and when dressed through silk gave a sample of flour such as could only be surpassed by the substitution of middlings-crushing-rolls for the final reduction, instead of mill-stones.

As Mr. Simon had described the Daverio-Simon middlings mill, he might be perhaps allowed to describe another mill for the same purpose, known as the "Carter-Turner" mill, which had been invented three years ago by Mr. J. Harrison Carter. The mill was shown in Fig. 4. The rolls were three in number, *b b b*, made of chilled cast iron, turned and ground to a smooth surface of mathematical accuracy. The spindles were of steel; they ran in bearings having a length of about four times their diameter, lined with phosphor-bronze, and having a self-acting lubricating arrangement, by which the oil was kept flowing continuously from

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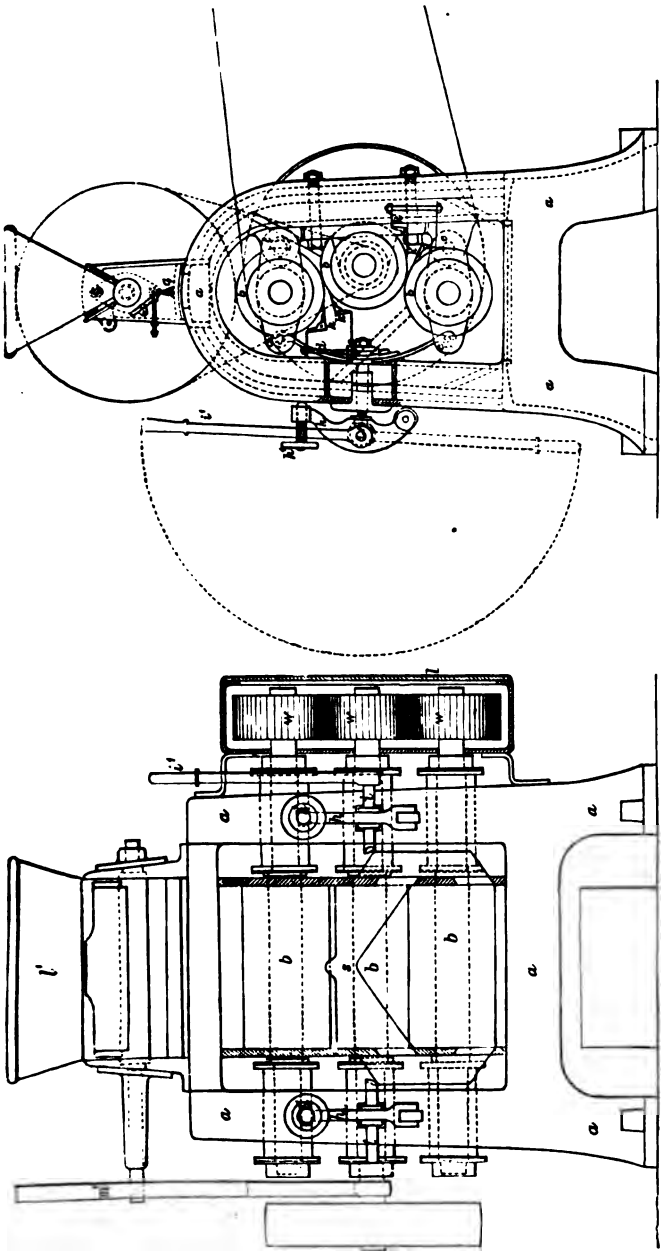
Mr. Turner.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Mr. Turner end to end of the bearings, but without the means of escape. The centre roll-bearings were fixed to the mill-frame. Those of the upper and lower rolls had projecting arms *c c*, by one of which they were hinged to the frame, and by the other were coupled to connecting bow-springs *d*. Each of these springs was grasped at its centre by a clip *e*, the stem of which passed through and was supported in the frame, terminating in an eccentric ring *f*, formed in the short bent levers *h*, shown outside the frame; by means of these levers and the adjusting screws h^1, which they carried at their upper ends, the relative positions of the rolls to each other were regulated with the greatest nicety. The pressure was then applied by the hand lever i^1, acting on the eccentric axis *i*; by turning this handle down the rolls were brought into contact with a pressure due to a multiplication by nearly 100 of the force applied. On again raising the handle contact between the rollers ceased. The gear wheels *w w w* were of various proportions, mostly giving a relative speed of 5 and 4 to the rolls; they ran in an oil-tight case *l*, the lower wheel dipping in a bath of oil kept them all constantly lubricated, so that they ran practically without either noise or friction. The frame *a* was made in one casting, thus giving great rigidity, which was very important in keeping the rolls true with each other. As Mr. Simon had explained of the Daverio-Simon roll, the three rolls did the work of two pairs, a peculiar feature in this mill being the mode of dividing (splitting) the feed by discharging it on to a wedge-shaped bar *q*, on either side of which the middlings flowed in approximately equal streams to the rollers, from which it was stripped by steel scrapers *k*, k^1, that from between the upper and middle rolls falling on to an inverted V-shaped trough *s*, which spanned over the stream flowing to the lower roll, and delivered the material into the receiver below. Between two hundred and three hundred of these mills were now in use; some of them had been working day and night for more than three years, but without showing any signs of wear. There was no doubt but that rolls of this character, subjecting the middlings, either from break-rolls or from millstones, to a heavy pressure prior to the final dressing, effected a most essential process in the production of flour of a high quality.

Mr. Powles. Mr. H. H. P. Powles considered that sufficient attention had not been given in the Papers to the structure of the berry of the wheat. A dark layer next to the outer skin was nearly pure gluten. The quantity of gluten decreased towards the centre of the grain. In the old-fashioned milling processes the gluten, adhering strongly

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to the bran, was wasted with it; in the modern processes the wheat being gently cracked to pieces, and the bran expanded under the rolling system, the grains of gluten eventually fell off, and were saved with the flour. That made what bakers called a strong flour, the gluten holding it together, and allowing the fermentation to raise it into a spongy mass. Mr. Powles.

Mr. Thomas Horn said he had not had much experience of the roller-system, but he had seen something of its working. Mr. Baker's Paper left it doubtful which description of milling the Author preferred, millstones or rollers. There was probably no one present who had more experience in the matter than Mr. Baker, and his silence was significant; at any rate Mr. Horn inferred that the Author was inclined to the old-fashioned millstones, which, when nicely fitted-up, formed, perhaps, the most delicate machine that could be used for grinding. The statement in Mr. Simon's Paper with regard to the whiteness of the flour produced by the roller-system was so extravagant as to lead one who did not understand the question to believe that flour made by millstones was actually black. He had seen flour made from middlings ground through millstones, and he had seen the same kind of middlings made from similar wheat ground through rollers, and the former was whiter and better than the latter. When the roller-system was started the rollers were made to run at the same speed, but it was soon discovered that the meal was flaked, and then it was found necessary to introduce a differential speed, one roller going much faster than the other—approaching the plan of the old millstone. Finding that that method did not produce the desired effect, the advocates of that system began to groove the rollers, but no amount of grooving could at all approach the beauty of the dress of a millstone. He had made a small model, which would enable any one to perform the difficult feat of "looking through a millstone;" from this would be seen at once the beauty and correct action of a millstone, which appeared almost to have been formed by nature for the very purpose of grinding wheat. The roller-mill seemed to be nothing more than the old steel-mill, or coffee-mill, with the teeth cut outside the cylinder instead of inside. According to his experience the flour made from roller-mills was not so white or so pure as that made with millstones, because it never could be done with one operation; middlings had to be passed through the rollers several times, and thus became heated, and discoloured. Of course, it was largely a question of pounds, shillings, and pence. Wherever rollers were introduced it was evident that there must be an immense amount of other machinery Mr. Horn.

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Mr. Horn. to compensate for the enormous amount of cutting that took place with the rollers. He defied any one who used roller-mills to produce bran as flat and as perfect as could be produced through millstones. If a perfect bran was made through a millstone it was evidently less choked-up than the small particles that passed through rollers, which had to be sucked and drawn away by a variety of means, involving a great deal of time and expense. If millers would have their machinery made as perfect with millstones as they had with roller-mills he believed that nothing could touch them. The bed-stone should be quite straight and level, and the runner stone required to be a little taper until it got near the skirt, and then there should be a perfect surface for the remainder. Such an instrument, with the dress well put in, would last much longer than any roller-mills.

Mr. Fogerty. Mr. JOSEPH FOGERTY stated that in the early part of his life he had a great deal to do with the construction of large flour-mills entirely on the old system. In connection with his father he had put up and run about one-thousand pairs of stones in Ireland. He afterwards gave up the business; but of late years many of his family being millers, his attention had been a good deal directed to the system of roller-grinding, which had certainly produced in the manufacture of flour as great a revolution as the spinning-jenny had produced in the manufacture of cotton. He knew of nothing more interesting than the manufacture of flour, and certainly nothing could be more important to the community. Having been recently in the City of Budapest, he had taken the opportunity of examining some of the large roller-mills in operation there, and from what he had seen he was led to differ entirely from the view that it would be necessary to adhere to or return to the old system of grinding by millstones. If any one would consider the action of a millstone in crushing and reducing to a fine powder the wheat berry, he would see at once that the corn had to pass over a considerable heating surface. The action of the grooved surfaces in millstones was precisely the action of a rough pair of scissors. At the first contact which took place in a 4-feet millstone, between 6 and 9 inches from the eye, the bran was rubbed off and generally removed; but as the flour proceeded towards the skirt of the stone the friction became closer, because the millstones were so adjusted that a very slight clip was given at the inside, but at about two-thirds of the diameter the stones were almost in contact. During the grinding process much heat was set up, which was very injurious. Another thing also took place which ought not to be overlooked. The wheat berry con-

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tained a dark substance at one end, which was the germ. It was the grinding of that dark germ which so much discoloured the flour, and if it was possible to abstract it from the berry, the flour would be of a much better quality. That was the object sought to be accomplished by Mr. Buchholz's roller-system of grinding, to which the millers of the world, and especially the American and Hungarian millers, were greatly indebted. Perhaps there was no more important scientific discovery than the fact that, by using rollers, the dark germ could be expelled from the wheat berry, leaving behind a better class of flour and the semolina. Mr. Horn had spoken of the great advantage of cutting the bran from the wheat at the first operation between millstones, and delivering it in a large flaky state. That was a tradition amongst buyers of bran, for what reason he did not know. Bran contained but very little nutriment, it was mostly silex, and whether cut into small portions or delivered large it made no difference to the consuming animal. Dealers liked to see large bran, but they would get over that idea when they could obtain it no longer. Millers cared very little for bran, forming as it did but a very small portion of the product of a sack of corn manufactured into flour. From what he had seen of the roller-system at the Agricultural Hall and at Budapest, he believed the time was not far distant when very few stones would be used in any mills of importance. They would probably remain in small mills in the country where millers would not care to erect new and expensive machinery. He was sorry that Mr. Baker's Paper had not explained the previous improvements which had been attempted in grinding flour by means of millstones, and dressing it through silk, especially the ingenious machinery introduced some years ago by Messrs. Swayne and Bovill, who purchased and largely applied a patent. This patent was applied in the great city mills near St. Paul's and at the Government mills at Deptford, and Mr. Fogerty had applied it to many mills in Ireland. It attempted to deal with the difficulty of which he had spoken. A cold blast was driven with great power into the eye of the stone, and from the outside covering of the stone an exhaust fan took off all the hot "stive," and carried it away into a room, where it was deposited through bunting, and ultimately separated from the flour altogether. That was no longer necessary with roller-mills. Similar means, however, were still used in some of the mixed mills at Budapest. The flour was delivered as it came from the dressing silks cool and fit to be made at once into bread, which he believed could not be done under any system of grinding by stones. He did not see what objection there could

Mr. Fogerty.

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Mr. Fogerty. be to the system of differential rollers. At first the rollers were run at the same speed. Forty years ago his father had used iron rollers in Ireland through which the corn was passed and crushed before it reached the millstones, and they were run at differential speeds. They were not grooved, but were cast-iron rollers with rough-turned surfaces. The object of the differential speed was that the grain might be immediately touched and cracked, or reduced to powder and passed away rapidly without being heated as it was by millstones. After having seen and studied both systems, he was strongly of opinion that the days of millstone grinding were numbered.

Mr. Beaumont. Mr. W. W. BEAUMONT said that, in alluding to the old grinding system, Mr. Baker showed some indication of his preference for it, adding that those who did not adopt the new machinery were supposed to be non-progressive. He then gave a clear exposition of the claims of different systems of milling, and referred to the half-high grinding system as best adapted for England generally, except seaport towns. Referring to the cost of labour in mills on the new system, his opinion appeared to be that it was greater than in the old mills. Mr. Simon, however, had expressed an opposite opinion:—"A roller-mill on the automatic system, with a capacity of, say, 40 cwt. of wheat per hour, should take no more than two or three men to work it. A stone-mill of corresponding size would require four or five men, besides the stone-dresser." It would be interesting to know whether those figures were the results of the different experiences of the Authors; whether it was a mere matter of opinion, or whether they were referring to different things. In alluding to the high-grinding systems, Mr. Baker had referred to the different form of dress adapted for millstones, stating that the furrows had to be much larger and the lands consequently smaller than in millstones for ordinary work. At the same time he expressed an opinion that the cost of a mill in England would generally be less under the half-high grinding system than on the roller-system. In one of the other Papers the cost of millstones was put at about £15 a year, running day and night. It would be interesting to know whether by so reducing the width of the lands the life of a millstone would not be very much reduced. All the Authors appeared to agree that the rounded groove was a mistake. Perhaps those who had had a good deal of experience with roller-mills would state their opinion upon that point. Mr. Baker had stated that the cost of a mill under the new systems would be greater than under the old systems. The buildings would have to be larger, and the quantity

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of machinery for the same quantity of work much greater. Mr. Simon, however, was of opinion that the cost would be less. He had mentioned the case of a miller who was under the impression that a roller-mill could be got for nothing, because it would cost him so much a year to dress his millstones, and that sum capitalised would represent a sufficient amount to build a roller-mill. It was only fair to ask whether roller-mills did not wear to some extent, and whether, therefore, there was not some cost attached to their maintenance. Mr. Beaumont.

Mr. Hugh James Sanderson observed that Mr. Baker had drawn particular attention to the system of Messrs. Nagel and Kaemp, and had stated that with certain wheats it would produce good results. He might be permitted to mention that with that system any kind of wheat could be worked. Their method consisted chiefly in the fact of the rollers working without differential motion. The wheat was treated on the low-grinding process by simple pressure and without friction. By means of the dismembrator they separated the particles of the grain which had been crushed asunder and caked together by the operation of rolling before they passed to the dressing machines. The inventors of the machine held that the pressure on the wheat, the middlings, the bran and the various substances which came under the roller, was not enough to generate sufficient heat to deteriorate the quality of the flour. That, he thought, was a fact which would be admitted by those who had had experience with the system. The wheat was placed between smooth chilled iron rollers with heavy pressure, sometimes as much as 6 tons, on a surface 2 feet wide, passing with such rapidity through the mill and through the dismembrator that the heat generated was not sufficient to damage the flour. That had been proved to the satisfaction of millers in an article written by the editor of the *Miller* (November 1881), who had examined one of the mills erected under that system. The dismembrator was a machine little understood. It ran at three thousand revolutions per minute. The disk was 2 feet in diameter, and as much as 6,000 lbs. of wheat had passed in an hour between two of the disks, so that it had not sufficient time to become hot during its passage. He was in a position to contradict entirely the statement of Mr. Simon as to the percentage obtained under the low-grinding processes by rolling mills, namely 68 per cent. as against 75 by high grinding. It would be new to those who had experience in the matter to hear that a higher percentage of flour could be obtained by high-grinding than by low-grinding processes. The low-grinding process was certainly more simple; the wheat Mr. Sanderson.

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Mr. Sanderson. passed through fewer machines, and the loss was certainly not greater. He had erected many mills on the low-grinding system for the roller-process, and in one case, as an example, taking the unclean wheat as it went into the mill and the flour sold from it, the percentage was 74½ in three months' running. The flour was chiefly sold in the neighbourhood of London, and was considered to be of a high class. He agreed that for hard wheats the high-grinding process had an advantage, and had been adopted by them, but he denied that that was the case with soft wheats. In some extreme cases it had been found that the flutes of the rollers had become clogged in grinding soft wheats, but he was of opinion that for soft wheats generally and for moderate mixtures of hard and soft, the low-grinding process with roller-mills had the advantage in the percentage and in the quality of the flour.

Mr. Giles. Mr. A. GILES did not profess to know anything about milling, but he had written to a friend who was both a practical and a scientific miller, sending him a copy of the Paper, and inviting him to take part in the discussion. His friend had replied, "There is nothing new in the Paper sent." His friend had forwarded him a pamphlet in which Mr. Chisholm of Chicago had described the process of getting rid of the germ (which appeared to be the great desideratum) by means of a machine which he had entitled the "degerminator." He merely rose to ask if any practical miller could give any information with regard to that system?

Mr. Nevill. Mr. H. W. NEVILL remarked that, as a baker, he at all times gave preference to stone-ground flour. He saw several gentlemen present whom he had been compelled to ask to send him no more flour ground on their new systems, but to go back to the old-fashioned method, which certainly met the requirements of the London public. He believed if they ground flour from good wheat on the old method, they would supply good flour. Hungarian flour did not suit the purpose of his trade.

Mr. Redman. Mr. J. B. REDMAN said that an incidental reference had been made in Mr. Simon's Paper to the frequent and rapid extension of fires in flour-mills. A few years back the large city mills of Messrs. Ponsford were gutted, and the upper part was materially damaged by fire. Shortly before that the large flour-mills on the Surrey side of Waterloo Bridge were destroyed by fire. A small stone-mill in the east of London, with which he had had something to do, was on two occasions gutted by fire within a period of five or ten years. The late Professor Rankine made an exhaustive report upon a large flour-mill fire at Glasgow, in which he sug-

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gested that the fire was extended by floating atoms of dust in the mill. An analogous question had also occupied the attention of mining engineers in reference to the extension of fire-damp fires by coal dust. It was claimed in Mr. Simon's Paper that the roller-system was less liable to produce fire than the old stone-system; if that were the case, it was certainly an important point in its favour. Mr. Redman.

Mr. J. Harrison Carter thought some reply was due from him to the statement of Mr. Nevill that roller-mill flour was not satisfactory. Mr. Baker had pointed out that any plan to be successfully introduced must take into account the quality of flour required in a district. Mr. Nevill's district was London; and, in regard to London flour, Mr. Baker had said: "A mill suitable for Glasgow, where fine flours are largely consumed, would not be suitable for London, where the bulk of the demand is for medium grades." He had not had one of Mr. Nevill's loaves on his breakfast-table that morning, but he had some of the best bread that could be procured from the ordinary baker; and he considered it a great misfortune that he was unable to give his family as good bread as could be procured in other towns. Many persons from different parts of England had lately been to Glasgow to see the systems in use there, and all of them with whom he had conversed had praised the magnificent bread produced in that city. Lord Provost Ure, one of the principal millers in Glasgow, had stated at a meeting of the operative millers of the city:—"That from the size of the present meeting it might be imagined that the milling trade was increasing in prosperity with the size of the city, and that as the community extended and the necessity for providing them with good flour increased, the means of meeting the demand was increasing likewise. He hardly required, however, to remind his friends on the platform that it was not so. With the great increase of the city of Glasgow the necessity for more millers, or even for the millers already in the field, was not by any means so great as very many of them would like it to be. Naturally it might be asked, Why was this? They would require to go back a few years to be able to give the reason. He believed it was probably the fault of the masters, and the men as well, a few years ago, that they didn't then keep pace with the times. There could be no question that some five or six—or perhaps eight or ten—years since the flour made in Glasgow was not by any means so good as that which might be got from other countries, and the consequence was that these other places producing a better quality had got a footing in Glasgow from which he feared it would be Mr. Carter.

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Mr. Carter. extremely difficult to displace them. It would naturally occur to all of them that what was wanted for the purpose was getting the best machinery in their mills." Since that time a number of roller-systems had been introduced into Glasgow; and, instead of many mills being closed, he believed most of them were now in full work. The quality of the bread was far better than that made in London. Indeed, those who had travelled through Ireland and Scotland—even in the remote districts—knew that they could get better bread there than in London. That should be a warning to English millers not to wait for the foreign miller to get a footing in this country, from which it might be difficult to oust him. He was glad to find that many were preparing to keep off the bad effects of foreign competition. Mr. Baker had warned millers of the difficulty of procuring a plant which would treat all kinds of wheat, and he had referred to the various kinds of wheat which the English miller was called upon to treat, two-thirds being foreign wheat, and most of it therefore considerably harder than native wheat. Mr. Baker would have them believe that, for hard wheats, the roller-system was superior to the millstone-system, and for soft wheats he was very emphatic in stating that the roller-system was inferior to the old method. His idea was the prevalent one that a millstone could not injure English wheat so much as it did foreign wheat, because it was tougher, and more able to resist hard treatment. That, however, was only a relative amount of injury. That a millstone must give bad flour from English wheat would be obvious on looking at the formation and substance of a millstone and of a roller-mill. A millstone was more or less porous, and continued to be so as it wore away; and it presented a greater rasping surface than a roller-mill. Then the shape of a millstone was not favourable to getting the flour away from the bran without pressure. The wheat had to travel over a large area. Any machine through which the wheat had to pass took off from the outside a considerable amount of dirty dust. If only another spout were put up leading from one machine to another, the very fact of the wheat running through that spout would take off some of the dust. If that were so, how much greater an amount of dust would be taken off when the wheat had to travel between the stones a long distance. Roller-mills opened the wheat into two or three pieces, and the flour was seen in its natural state. With sharp roller edges the flour was detached, some in the form of flour, and some in the form of semolina; but with the flat land of the millstone the flour taken off was by frio-

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tion, and when the bran was reached it was taken off by a considerable amount of pressure. He could best exemplify the advantage of the roller-system by stating that the flour from highly-ground bran was much better when taken off by a roller-mill, than when taken off by a millstone. When millers used roller-mills for re-grinding highly-ground millstone bran, they could not from that bran procure a flour of so good a quality as they could when, with the last fluted roll in the break-system, they took off the remaining portions left by the previous roller. He did not think it was any exaggeration to say that the flour taken off by the last fluted roller in the gradual reduction system, was nearly equal in quality to the ordinary straight-run flour made by millstones. Many millers might laugh at the statement, but they might easily obtain proofs of its correctness by seeing the roller-system at work, and testing the flour produced. He would undertake to procure flour from his last fluted roller, with which Mr. Nevill could produce better bread than could be made from the ordinary "households" of the City of London. Mr. Carter.

Mr. W. E. Rich remarked that the Papers were deficient in regard to the question of the power required for the various systems. The only reference to the subject was a statement, in Mr. Simon's Paper, of some very hazy and roughly-determined results. The authority of Mr. Otto Mueller, of Budapest, was given for the statement, that in stone-mills the quantity of wheat ground per indicated HP. per day of twenty-four hours, was only 3·15 cwt. He believed that twice that quantity of wheat could be so treated, and if a comparison were founded upon that statistic, it was erroneous. He had been himself accustomed, in experiments that he had made in corn mills, to determine the statistics by the HP. per bushel of 61 lbs. of meal per hour. In 1869, by permission of Messrs. Belben, of Poole, he tested with Richards' indicators on their steam-engines the power consumed under various circumstances in their mills, which then contained ten pairs of 4-feet stones, worked by belts at one hundred and forty revolutions per minute, with blast and exhaust, grinding from 7 to 8 bushels per pair of stones per hour. The mill and its machinery generally might be taken as a sample of a first-rate stone-mill at that time. In an elaborate series of experiments he tested the indicated power, first with ten pairs of stones at work, and then successively with nine, eight, seven, six, five, four, three, two, and one pair of stones, the meal ground per hour in each experiment being at the same time accurately weighed. The power required for smut- and dressing-machines was also tried; then the mills with belts and gearing Mr. Rich.

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Mr. Rich. were all driven light; and finally the belts were disconnected, and the engines had only their own friction and that of the shafting to overcome. For comparison with Mr. Simon's statistics he might summarise the results of his experiments at Poole, for the power required in a ten-stone mill in 1869. Taking eight pairs of stones as the average number working at one time, and one pair of these grinding tails over again, the net results from the average of two sets of experiments were as followed:—The seven pairs grinding wheat ground 58·6 bushels per hour; but allowing 5 per cent. for irregularities, the net result on a day's working was 55·7 bushels per hour. The power required at the same time was:—

	Net indicated HP. with eight pairs of stones working.	Indicated HP. per bushel per hour.
For eight pairs of stones	53·1	0·95
For two smut-machines	5·6	For cleaning, dressing, and sundry machinery, shafting and engines 0·50
For two dressing-machines	1·4	
Friction of shafting and engines . . .	13·5	
For sack-hoists and other machinery, 10 per cent.	7·4	
Total	81·0	1·45

Thus it appeared that at that date the Poole mills, which then chiefly ground clean English wheat requiring little smutting, could grind and treat a bushel of wheat with an expenditure of 1·45 HP. per one hour, corresponding to 9 cwt. of wheat per indicated HP. per day of twenty-four hours. Ten years later he visited the same mills again; he did not go through the same experiments, but he was surprised to find a great increase of machinery for smutting and cleaning the foreign wheat of the great amount of dirt and other things which came with it, and on inquiry he found that the HP. consumed for the mills generally per bushel had been much increased. As far as he could gather from approximate figures then given to him by Messrs. Belben, the power had increased about 35 per cent., making the total indicated HP. required in a modern stone-mill about 2 HP. per bushel per hour, in consequence of the introduction of the new machinery. There were no roller-mills, nor were any contemplated, though the mills had to be extended. The intention was to increase the engine power and speed of driving, and then increase the output to 9, or possibly 10 bushels per pair of stones per hour.

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Sir Frederick Bramwell.

Sir FREDERICK BRAMWELL said Mr. Nevill had remarked he did not like roller flour, and that it did not answer his purpose. Mr. Nevill was a maker of London bread. Sir F. Bramwell thought that all who had travelled throughout the United Kingdom, and in various foreign countries, must agree that when they left London they got into a region of better bread. Although it might be a fact that an experienced baker like Mr. Nevill was enabled to make London bread from flour produced by the old process, and to make that bread well, he thought that a better test of the quality of flour might be found in ascertaining what could be done by an amateur baker. He should like to give his own domestic experience upon the subject. London bread, to his taste, was so nasty—it was either overwhelmingly salt, or very sour—commonly both, the salt being put in to cover the sour—that he never eat it if he could avoid it. Acting on this for some years past he had been in the habit of having his bread made at home, with a very satisfactory result as a whole, varied, however, by occasional failures, but fortunately, "from information he had received," he had been led to discard English flour and to substitute Hungarian (roller flour), and from that day to the present there had never been the slightest difficulty in the bread-making. He did not think there could be a better test of the quality of an article than the finding that inexperienced hands could not go wrong with it; while with another make they not unfrequently did go wrong, and that it required an amount of skill which ordinary cooks did not possess, to make good bread from the old-fashioned flour. With all respect to Mr. Nevill and to Mr. Horn, he thought the roller system was one that should commend itself to the meeting. He was sorry that Mr. Proctor Baker, the Author of the first Paper, could not be present, because he was a gentleman who could express himself extremely clearly, and give a reason for the faith that was in him; and if he had taken part in the discussion he felt sure Mr. Baker would have made very evident what he thought of the different modes, and would have stated the various circumstances under which any one of them was to be preferred. Allusion had been made to the connection which he (Sir F. Bramwell) had many years ago with an improvement of the old mode of milling. Prior to that improvement the system of milling in England was certainly simplicity itself. Perhaps there was some kind of machine to clean the wheat, and perhaps not. A pair of 4-feet millstones moving at one hundred and twenty revolutions per minute ground, when they were freshly dressed (the wheat being in good order), 4 bushels an hour,

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Sir Frederick Bramwell.

gradually falling to 3, or to 2½, as the stones became dull. Even at that low rate the meal produced was in such a heated condition that it was impossible to proceed to dress it at the moment; it had, therefore, to be put into sacks and allowed to stand until it cooled. When at the end of, say, forty-eight hours it had become cool, it was put through a dressing machine which was of an extremely primitive character; he was not speaking of the bolting machine, but of the wire-dressing machine, a fixed cylinder lying at a slight angle covered with wires of various degrees of fineness and having within it a spindle armed with brushes which, partly by centrifugal action and partly by sheer brushing action, drove through the wires such material as would go through its meshes, wholly irrespective of what that material was so long as it was small enough, and thus was produced the flour so highly prized by Mr. Horn. It would be seen that the process was not automatic, but required hand-labour at every point. Through these dressing machines a certain quantity of granular flour passed called "middlings" or "sharps," and in that condition not fit for sale. It was put through the millstones and re-ground. The triumph of the miller was to make as few "middlings" as possible. If he made many he was thought not to understand his business and not to know how to dress the stones. Thus the production of "middlings" flour, selling at a lower price and principally used for biscuit making, was the disgrace of the miller, while in the modern processes his aim is in effect to make the greatest quantity of "middlings" possible. That was the condition of milling in England about thirty-five years ago. At that time the French were making far better flour than the English. Instead of dressing it through the *machine brutale* used in England they were dressing it through silks, which were stretched upon hexagonal or octagonal frames, 3 feet in diameter and 20 feet or 30 feet long, lying at a slight incline and slowly revolving, being fed with the meal at the upper end; as they revolved they raised the ground products up to a certain height, and these products then fell through the interior of the reel on to the silk below, and in that way they were gently sifted through silks of varying fineness. By that process the flour was greatly improved. On inquiring how it was that this improved flour could be made in France and not in England, the observation was made that the people of England had not been cultivated to use a good flour, and that there was no market for it—that they had to be taught the difference between good and bad, or inferior, flour. It was also said that the French process required a drier wheat than the native wheat, and

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that it was necessary to grind it more slowly, so as to avoid heating. He believed he was right in saying that in those days the best French millers did not grind at a much greater rate than 2 or 2½ bushels per hour, while the English were grinding 4 bushels. The result of the use of drier wheat and of slow grinding in France was that the meal produced there was fit to be immediately dressed through the silks; and in that manner there was an automatic process resulting in the production of very good flour. In 1853 he went to the United States on a visit, and was greatly interested in seeing the milling processes of that country. Money was dear and wages were high; while wheat was cheap the great effort of the miller under these circumstances was to see how much he could produce out of a given amount of plant and labour; he did not care about cleaning his brans; in fact they carried away enough flour upon them to have ruined an English miller; it did not ruin the American miller because to him wheat was cheap. In order to obtain this large output, while the English were grinding 4 bushels he (the American) was grinding 12. The result was that the meal came out at such a temperature that when the hand was put into it it would be instantly drawn away as involuntarily as though it had been put into hot water. In those days the American flour was commonly good and strong, but sour. That was the condition of milling in America in 1853. He had not been there since, but he knew as a matter of engineering reading, that that state of things had entirely passed away. This far-seeing and clever nation, whenever there was an improvement made, either native or foreign, wisely adopted it, while others stood by and let things "slide." The object of the improvement (the invention of a foreigner) in the old mode of grinding introduced by the firm of Swayne and Bovill, for whom he had been for some years manager, was to get rid of the generation of heat in grinding flour, and also to prevent what was technically known as killing the flour. In considering that which went on in ordinary grinding, it would be seen that the wheat was crushed near the eye of the stone, and in that first crushing some flour was produced; but as the flour could not get away except by reason of the lead of the furrows and the centrifugal action, it remained between the stone surfaces, clogging the stones and subjecting itself to the triturating effect of the stone generating heat. The invention consisted in the introduction of a blast to the eye of the millstone, which for this purpose was closed by a plate, through which a tube went to introduce the feed of corn. This tube was in itself a novelty in England, although well known on the Continent, the

Sir Frederick Bramwell.

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Sir Frederick Bramwell.

feed of corn in England being made with the old shaking shoe, used in the time of Chaucer, but there was great difficulty in using such a feed as the shaking shoe with the blast; and one of the obstacles to the introduction of the blast system was that the shaking feed had to be replaced by the tube, or "silent feed," as it was called. It was almost impossible to get a miller to adopt the "silent feed"; he had been in the habit of seeing the shoe, and of hearing it make a noise. To humour the fancy of millers, attempts were made to employ the shoe feed with the blast, and these attempts were after much trouble successful; but as a rule with the blast the silent feed was adopted. The eye of the stone was covered by a plate, which was fixed upon the stone case. There was a cylindrical leather dipping down from the underside of the stone case to a ring on the back of the millstone, where the leather was loaded with segmental weights, which, pressed against the ring, made a sufficiently air-tight joint. In that manner it was practicable to maintain within the eye of the stone a pressure of air equal to about 1 inch of water. Having that pressure in the eye of the stone, and the only exit for the air being between the surfaces of the stones, it was clear that when there was anything between those surfaces so small that it could pass away, the air in its passage from the eye to the outside would instantly take it away: and thus it was that the stones were never employed in "slaying the slain." When the flour was once produced they did not kill it, as the wind laid hold of it and removed it. And not only was the generation of heat prevented by the flour being thus carried away from the action of the stones, but that which did remain under the action of the stones and was heated was forthwith cooled by the passage of the air over it. Moreover, as the air became heated in passing between the stones, it became more greedy of moisture, and took it up from the meal, and in that way it could and did materially dry it, and by the introduction of the blast render it more fit for immediate dressing. Instead of grinding 4 bushels per hour per pair of stones, and having meal produced in a condition in which it could not be at once dressed, and could not be successfully dressed through silks at all, except at certain times of the year, and when the wheat was in a certain condition, there was a two-fold production got out of the same milling plant, and the meal was delivered in a state in which it was thoroughly fit for dressing immediately, and by a continuous process, through silks. He did not wish to be understood as suggesting that the increased production was obtained without a corresponding increase in the power employed. Taking

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the millstones alone, there probably was some saving of power, but after allowing for that needed for working the fans, he believed that practically just as much power was needed per bushel of wheat ground whether the blast was or was not employed. He would not follow the speakers or the authors into the question of the roller system, because it had been amply discussed; and his only reason for rising was that his name had been referred to in connection with that which was now of interest as a step in the art of corn-grinding, rather than a matter of present interest, having regard to the improvements brought forward by roller grinding. Sir Frederick Bramwell.

Mr. SIMON, in reply upon the discussion, said he was aware that the system advocated by Mr. Sanderson gave good results as far as the percentage or quantity of flour was concerned. When speaking of the bad results of low grinding with regard to percentage of flour, he meant to refer to the attempt that had been made of low grinding by roller-mills with only two or three breaks, and a corresponding rapid reduction of the semolina. This did not produce practically more than 68 per cent. of flour, as against about 75 with a sufficient number, say five to seven, of breaks by rollers. Where there was capital enough to pay for the increased machinery, six or more breaks were to be recommended. In a mill in Spain recently erected with Daverio roller-mills, eight breaks were now used, and some Swiss and German millers employed nine with excellent results. Mr. Simon.

With regard to Mr. Horn's opinions, it was hopeless to attempt to deal with them now. He should carefully read the whole of Mr. Simon's Paper over again, and he would find each of his assertions refuted. Mr. Horn had asserted that broad bran could not be produced by rollers; but several experienced millers, for whom Mr. Simon had erected mills, had assured him that they never saw such splendid bran as they obtained by his system. Besides, there were the samples exhibited on the table to testify to the fact. All the data adduced by Mr. Simon were the results of years of practical experience; there was no exaggeration in them, either with regard to quantity or quality of products. How was it that in all those countries in which milling was most advanced, the stone was being superseded rapidly by the roller-mill, as in Austria, Germany, Switzerland, and the United States? Quite recently the same movement had begun to be manifested in Italy, Spain, and even France. A mill of considerable size was at the present moment being filled with Daverio rolls at Marseilles. This question had now been decided by the law of "The survival of the fittest."

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Mr. Simon. A remark had been made about the space required. He had erected a roller-mill in the space formerly occupied by eight pairs of stones. That mill was now doing the work of between thirteen and fourteen pairs of stones. The space required was therefore considerably less for roller-mills on his system.

As to the possibility of grinding hard and soft wheats, his experience proved that, whatever the wheat, the results attainable by rollers were in every case superior to those obtainable by stones. One of his clients often ground soft Lincolnshire wheat on his machines, and many others were habitually using from one-third to two-thirds of English wheat in their mixtures.

His statements as to labour were the results of experience in mills constructed by him, and at work in this country. He thought the reference to Mr. Baker's opinion, that half-high grinding was generally best adapted for England, did not apply to half-high grinding by stones only, but by rollers. He believed that half-high grinding by rollers gave superior results to half-high grinding by stones; but that high grinding by rollers afforded superior results again in comparison to half-high grinding by rollers. He had already stated that high grinding by rollers gave nearly 10 per cent. more flour than low grinding, and the results of half-high grinding were necessarily intermediate between low and high grinding. A miller would make more money out of a given quantity of wheat by high grinding than by either low or half-high grinding. There was the experience of all the well-known milling countries to go upon, and it was past a matter of "opinion." These were facts. As to the cost of repairs of roller-mills, every machine wanted repairing after prolonged use, and he supposed that the stone and the roller-mill would in the long run not show much difference in this respect. The £15 a year, however, for stone-dressing were not so counterbalanced in the roller-mills, as only the grooved rollers required recutting after from one year to four years' use, according to the fineness of the grooving, and that should only cost about £1 per roll. The Chisholm machine was well-known in this country. The results given by it could not be compared with those by proper roller milling. It was a cast-iron millstone, with the working surface much reduced in width. No doubt, if properly worked, it might yield fair results if contrasted with the work of the ordinary millstone; for the time of contact of the grain with the working surface was much reduced, but still much too long; much longer, indeed, than in the roller-mill, where the stuff to be ground was never touched by the working faces for more than a very small fraction of a second at a time, viz., while

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passing across the mathematical line of contact between the rolls. Fire insurance companies took considerably smaller premiums on mills using the pure roller-mill system. Mr. Rich had spoken on the subject of power. He seemed to have overlooked the information given in his Paper directly after that mentioned by him. Mr. Simon there gave the results of three different mills built by him in England and Ireland. The average was the grinding of about 45 lbs. of wheat per HP. per hour; and this, having regard to the very superior results in quality as compared with those to which Mr. Rich's remarks could only refer, namely, low grinding, seemed very satisfactory. In fact these results had recently been exceeded in other mills, and 66 lbs. of wheat had been ground per HP. per hour. Mr. Simon.

Sir W. G. Armstrong.

Sir W. G. ARMSTRONG, President, said the members had had the advantage of listening to a very instructive discussion on a subject which, so far as he knew, had not been previously before the Institution. They had learned much about high grinding and low grinding, about old-fashioned stones and new-fashioned rollers, and he was sorry that his acquaintance with the subject was not such as to enable him to throw any further light upon it. Indeed he might say, "When doctors differ, who shall decide?" Certainly he could not pretend to do so. He might, however, remark that he did not think there was to be found in the whole range of mechanical science a more remarkable instance of an elaborate, and highly efficient process arising by evolution from one of a most rudimentary character. If they contemplated the rude process followed by their forefathers of simply pounding grain by manual labour in a mortar, and then compared it with the modern corn mill in which the pulverisation was effected in an infinitely more perfect manner, without any labour at all, and in which all the crudities of the grain were separated with such perfection as to leave scarcely an atom behind, they could not fail to be impressed with the extraordinary advance that had been made by experience and science in that most important industry. With respect to the quality of the material regarded as a food there might perhaps be some difference of opinion. Many high authorities assured them that the coarsely ground grain, containing all its natural envelopment, was the more wholesome food. It was possible, therefore, that they might be over-refining their flour, just as it seemed to him they were in these days over-refining their civilisation. A little more nature and a little less art might be of advantage both in their meal and in their manners. But those considerations belonged rather to the domain of social science than to that of

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Sir W. G. Armstrong.

engineering science. Their function was to obtain an object in the best possible manner by mechanical means, and certainly the modern system of corn-grinding appeared to be a triumph of their art.

It only remained for him to say a few words with regard to the proceedings of the session. All the Papers had been of unusual interest. They had for the most part taken the form of dissertations upon broad mechanical subjects rather than descriptions of works. No doubt Papers of both kinds were desirable, but Papers such as they had had lately were more favourable to discussion. From what he had heard and read of the discussions he thought they were highly creditable to the Institution. They had displayed a very wide acquaintance not only with Mechanics but with Physical Sciences in general, and they had also shown a very considerable debating power on the part of many members. With regard to the work of the Council it had embraced the consideration of 50 applications for transfer, 250 for election into the Institution, and 150 for the admission of students. Death, as usual, had removed many names from the register, but they now numbered of all classes 4,159 against 4,005 twelve months ago. That showed an increase of 4 per cent., and when it was considered that the increase was really taking effect in the nature of compound interest, he really did not see how they could go on much longer without a very large extension of their premises, or possibly an entirely new building, either of which would involve very serious financial considerations.

Correspondence.

Messrs. Nagel and Kaemp.

Messrs. NAGEL and KAEMP observed, regarding the difference between high grinding and low grinding, and also as to the respective merits of the two processes, that the most correct definition which, up to the present time, had been given, was undoubtedly that of Professor Kick :[1] "High grinding consists of that method of reduction by means of which the largest proportion of the total flour produced is obtained from the purified middlings; low grinding, of that method by which the largest proportion of flour is obtained from the first reduction of the cleaned wheat." Both processes had for years been used, and the choice between the two had been made in accordance with the particular demands

[1] Die Mehl-fabrication, Leipzig, 1878, p. 287.

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of the various districts, and more especially with regard to the nature of the wheats most advantageously obtained. Messrs. Nagel and Kaemp.

The brilliant results arrived at by Hungarian millers, in respect both of quality and quantity of the flour produced, had attracted the attention of all millers for many years before the introduction of Wegmann's roller-mills, the date of which coincided with the advent of the subsequent almost total revolution in the art of milling; and long before the introduction of the modern roller-mill the greatest efforts had been made, both in England as well as in nearly all countries where low-grinding had been carried on, by adopting the Hungarian method to produce results as favourable as those obtained in Hungary itself. And why, might it be asked, had these great efforts been almost altogether without avail? Chiefly because too little attention had been given to the peculiar nature of the Hungarian wheats. Whoever had given himself the trouble of making the experiment of grinding hard and brittle wheats by the low-grinding process, and also soft wheats by the high-grinding process, had learned from the results that the flour produced by the former contained many small particles of broken-up bran, and the flour itself was more in the form of very fine middlings than the usual nature of flour. On the other hand, the flour obtained from the soft wheats, although good in quality, would have been produced at too heavy an expenditure of power, owing to the large amount of machinery used in excess of the actual requirements. In moist northern climates the wheats to be dealt with were chiefly of a soft nature, the bran of which was tough, whilst in the south, under the influence of a hot sun, the native wheats were of a brittle nature, both as regarded the berry and the bran. The main object of every system of milling was to produce flour free from particles of bran, and bran free from flour, and this, too, with a minimum expenditure of power, labour, and cost of every description. It stood to reason that it was easier to achieve this object in the case of wheats, the berry of which could be readily broken up, and the bran of which was of a tough nature, than it was to deal with hard and brittle wheats where this was not the case. Mr. Simon had mentioned the artificial means frequently adopted to toughen the bran of brittle wheats either by wetting or by heating the wheat, but no mention was made of the great difference in the nature of the many and various kinds of wheat imported from almost all wheat-growing countries. English millers were much too enterprising to have so long delayed the introduction of the high-grinding process had the

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Messrs. Nagel and Kaemp.

necessity for this been to any great extent felt. It was only during a very recent period that the high-grinding process had been largely adopted in England, through the introduction of fluted roller-mills; and why had this change, so long delayed, come so suddenly and obtained so much favour? Simply because English millers quite unexpectedly found themselves all at once obliged to adopt it, either partially or in its entirety, owing to the large quantities of hard and brittle wheats which were forced upon the market from Russia, America, and India; and the simultaneous introduction into the country of large quantities of flour of a higher quality than that generally made in the United Kingdom. It was not unnatural that the above statements should be doubted, seeing that English millers had for years been in the habit of grinding hard wheat, imported from Hungary, America, and India, in conjunction with soft native wheat, in order to produce flour containing the necessary amount of gluten, the English wheats, although producing flour of good colour, being deficient in this respect. But this hard wheat had, up to recent times, been only, in the majority of cases, used in small proportions, and then only after being mellowed by mixing amongst the soft wheats before the operation of grinding commenced. The result of this mellowing process was that the bran of the hard wheats obtained from the soft wheats a sufficient quantity of moisture to give it such a degree of toughness as would enable the miller to reduce it by a moderately low-grinding process, and leave the branny particles of such a size as might readily be sifted out by the dressing machines. The statement that the percentage of flour which could be obtained from wheat by the low-grinding process was only 68, as against 75 obtained by high grinding, was altogether antagonistic to well known and acknowledged rules. It was acknowledged by experts that an almost exactly similar percentage could be obtained by both processes when the machinery was properly designed and worked, and the wheats were of the same quality.

In a work by the French engineer, Mr. Philippe Kremer,[1] he said that, in spite of his preference for the high-grinding process from a purely financial point of view, the result was the same whether the wheat was reduced by the high or the low systems. That from wheat weighing 78·5 kilograms per hectolitre, and costing 28·50 francs, produce to the value of 31·50 francs to 32·50 francs might be obtained, according to the quality of the wheat and the intelligence of the miller. This statement of Mr. Philippe

[1] "La meunerie française et les procédés nouveaux," p. 10. Paris, 1881.

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Kremer, however, was not quite correct, for there could be no doubt that, by reducing hard wheat on the high-grinding process with fluted rollers, the value of the product was much higher than it would be were the same wheats reduced on the low-grinding process by millstones. Those who were desirous of investigating the subject could easily do so by applying to the various treatises published on the milling industry, as well as to the files of trade journals published in England, Germany, Austria, Italy, and lately in France. The statement was as adventurous as it was incorrect, that the difference between the percentages of flour obtained respectively from the high- and low-grinding systems with roller-mills meant an extra profit of £3,000 per annum to the miller who ground 15 cwt. of wheat per hour by the high-grinding process. It could be refuted at once by millers of even moderate experience, and consequently there was very small probability of their being misled by it. Such a statement was dangerous when made before an assembly of Engineers, the majority of whom had doubtless interested themselves but little in this branch of the profession, and who, if suddenly called upon to advise their clients regarding the best system of machinery, might naturally be attracted by such brilliant prospects. To those conversant with the ordinary rules which governed business, it would naturally occur that, were there any truth in the assertion as to the extra profit of a mill (of 1,000 sacks of flour per week capacity) on the high-grinding roller-mill system, amounting to £3,000 in the course of a year, as against a similar mill on the low-grinding roller-mill principle, the certain result would be a great rush on the part of millers to the system offering such advantages. As a matter of fact, however, there were no signs of this, and those millers who had adopted the high-grinding system had, for the most part, been driven to do so, owing to the quantities of hard wheats which had been thrown upon the market in certain districts. Messrs. Nagel and Kaemp.

Where wheats of a hard and brittle description were ground alone, or with only a very small proportion of soft wheat mixed with it, Messrs. Nagel and Kaemp were decided advocates for breaking down the wheats by other means than smooth rollers, but whether the fluted rollers were the best machines for the purpose was a question which had yet to be solved. Long ago it had been asserted, by many interested in the trade, that this or that method of working was absolutely the best; and many had failed to take into account the vast difference in the nature of the wheats which it was necessary to work upon. The different conditions under which millers of various countries and districts had

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to carry on business were far too many to enable them to satisfy themselves with one universal system of milling machinery. The experienced tradesman would, on the contrary, continue to seek out for himself the mode of operation, and the class of machines which appeared to him to be best adapted to his particular requirements. There was undoubtedly a strong tendency in all fields of industry to carry on a process of manufacture in one common groove, instead of each individual making it his object to carefully investigate the mode of procedure for himself, in order to ascertain whether it might not be possible to introduce alterations which would enable him to adapt the process to his own requirements. It was also frequently found that those who followed out an idea were more enthusiastic than the originator himself.

Years ago a hot discussion was carried on in the trade journals as to the respective merits of porcelain and chilled iron as a material for manufacturing rollers. Was this discussion necessary, or had it been the means of clearing up the many disputed statements? Messrs. Nagel and Kaemp did not believe that it had done so.

It was not their intention to call in question the merits of what Mr. Simon repeatedly called his system of milling. Were they to do so it might perhaps with justice be said that their own proceedings might be called in question, in so far as they had for some years been engaged in the introduction of a new system of milling (exhibited at the International Exhibition of Milling Machinery held in Berlin in 1879), of which Mr. Simon, in his sketch of the progress of modern milling, made no mention. This system was shown at the International Exhibition of Milling Machinery held in London in May 1881, and was noticed at considerable length in the trade journals of the past year, and had been mentioned in Mr. Simon's Paper. They would further invite attention to Mr. Simon's remarks regarding the disintegrator, and especially to his description of their system of milling, where he had referred to the opinion of Professor Kick, who classed the disintegrator as a machine only suitable for low grinding. Mr. Simon had given four Tables of results obtained by his system of milling; and it was interesting to note that in Table No. 1, which represented the result obtained from uncleaned wheat, only ½ per cent. of loss or waste was shown; in Table No. 2 for uncleaned wheat, and in Table No. 3 for cleaned, no loss whatever was accounted for; whilst in Table No. 4, for uncleaned wheat, 1 per cent. loss was given.

In the case of the Austro-Hungarian mills, where high grinding

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was almost universal, and where, moreover, fluted roller-mills were chiefly used, it was customary to take into account a loss of between 3 and 4 per cent., even when the calculations were made from the cleaned wheats. (See Professor Kick in "Mehl-fabrication.") Messrs. Nagel and Kaemp.

As regarded the disintegrator, it had been shown (see A. C. Nagel's Paper, read before the Institution of German Engineers, 1879)[1] that this machine was not of necessity a power-absorbing instrument to any excessive extent, as it might be supposed to be from Professor Kick's remarks. That the disintegrator was not universally considered a machine which could only be advantageously used in a low-grinding process was best proved by the fact that, as made by them under the title "Dismembrator," it was now largely used in mills where only the high-grinding process was carried on. This was the case in Budapest, the metropolis of the high-grinding system. An Austrian miller, who for a number of years had used their dismembrators, had written to them that he considered the dismembrator the best machine extant for the purpose of producing middlings. Messrs. Nagel and Kaemp were not prepared to endorse this statement in its entirety; they only mentioned the circumstance in order to show that the machine was at least capable of producing semolina of excellent quality, and therefore not unworthy of being included in a system of high-grinding machinery. The dismembrator might be used for either hard or soft wheats; for high or low grinding in many different ways, and in particular stages of the process of reduction, it did excellent work where it would be difficult to find a suitable substitute when under careful control. When properly constructed and well handled it was not a machine which absorbed excessive power. On the contrary, experience showed (and since 1878 they had erected one hundred and sixty of these machines) that they might be worked with a surprisingly small amount of power. Every dismembrator, before leaving their works, was thoroughly tested by the dynamometer and indicator, and they were therefore fully aware of the actual amount of power absorbed by the machines under various circumstances. A dismembrator running empty, and at two thousand revolutions per minute, did not absorb quite 1½ HP.; at two thousand four hundred revolutions, not quite 2 HP.; at two thousand eight hundred revolutions, only 2·6 HP.; and at three thousand revolutions, only 3·3 HP. In short, the power absorbed by a dismembrator, operating upon 4,400 lbs. of crushed wheat per hour, did not exceed 5 effective

[1] Wochenschrift des vereines Deutscher Ingenieure, 1879, p. 385.

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HP. With double dismembrators the results obtained had been still more favourable. The question as to the absorption of power had been practically tested upon the frequent occasions when the roller and dismembrator mills had been brought into competition with millstones, often under the same roof, and when a saving of power—generally to the extent of 50 per cent.—by the roller and dismembrator process had been proved.

It had been further stated that the great heat evolved by the disintegrator was a source of danger, which caused the machines to be looked upon by insurance companies with disfavour. No doubt some disintegrators had been known to run dangerously hot in the bearings, but this had been due either to faulty construction or to careless attention. The very light belt by which their dismembrators were driven would refuse to do its work should the bearings become dangerously hot, and so retard the free motion of the machine, and the dismembrator would simply stop running. The continental insurance offices viewed the dismembrator in anything but an unfavourable light; and the amount of premium charged had, in the great majority of cases, been considerably reduced below the amount charged for insuring the millstone mills previously working in the same buildings, where their system of rollers and dismembrators has been subsequently introduced.

The advantage gained by a thorough separation of the grain from the flour had been shown by Mr. Simon, but he was probably unaware that the dismembrator had proved an excellent machine for this purpose. It had frequently been assumed, even by experts, that one effect of the dismembrator was to break up the bran; and Professor Kick had also been of this opinion, giving as his reasons the following: "The pins of the dismembrator must strike most severely upon the outward surface of the berry, which surface would consequently be most apt to part asunder. The bran, as the outermost part of the grain, would therefore be reduced to a greater extent than the body of the grain itself; the dismembrator is consequently constructed upon a wrong principle." To the uninitiated there might appear to be some truth in this; and Messrs. Nagel and Kaemp willingly admitted that Professor Kick would at least be partially correct were the physical conditions of the bran and the berry equal. This was, however, well known not to be the case. Mr. Simon had remarked that in some districts large flat bran was in the greatest demand, whilst in others only small bran was desired. This was true, and they had often enough experienced the facility with which they could produce

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the former, whilst they had found the greatest difficulty in producing the latter. This only confirmed what had been well known to them for years, namely, that the dismembrators actually protected the bran, instead of pulverising it, as had been assumed by Professor Kick. Messrs. Nagel and Kaemp.

It was well known that the sand-blast would at once affect the hardest glass, whilst the commonest zinc was scarcely touched by it; in consequence of which zinc was used to protect the glass. This was of course due to the difference in the physical conditions of the two materials, and would serve to illustrate the difference between the effect produced by the pins of the dismembrator when striking upon the bran and the berry of the grain respectively, leaving the former intact and at the same time reducing the latter to flour and middlings.

Messrs. Nagel and Kaemp had in these remarks endeavoured to elucidate the difference between high- and low-grinding, and also to clear up some misapprehensions of old standing with regard to the working of the disintegrator, which were still to be found even amongst engineers. It was their firm conviction that very few industries, and certainly not the art of milling, would be served by the propagation of the theory that one particular mode of procedure would be sufficient to give satisfaction to those endeavouring to attain the same end, but under widely differing conditions.

THE JOHN T. NOYE MANUFACTURING COMPANY stated that, in reading the Paper upon "Modern Flour-Milling in England," they were surprised at finding the following:— The John T. Noye Manufacturing Company.

"It may here be mentioned that an American inventor recently re-introduced in Europe the exploded idea of using rounded corrugations or flutings. A large number of his rolls were adopted by American millers, but many of these are being changed for rollers with sharp-covered flutes" (p. 217). They were entirely at a loss to understand this assertion; inasmuch as, first, so far as documentary evidence was concerned, there was none on record anywhere of the prior use of the rolls with rounded corrugations covered by the Stevens' patents which they controlled; there had therefore been no attempt at the re-introduction of round corrugated rolls; secondly, there was no foundation whatever for the statement that the rounded corrugations were proving unsatisfactory. On the contrary, no mills at the present time were doing such good work as those provided with round corrugated rolls. The sales of these rolls, extending over a period of two years, had aggregated some three thousand pairs, and perhaps they could offer no stronger

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The John T. Noye Manufacturing Company.

evidence of their value, and of the favour in which they were held by the milling fraternity, than to mention that the demand for them was greater in the present year than at any previous time. Their value had been acknowledged by those who made the rolls with sharp corrugations, as was instanced by the fact that, to meet the demand of their customers, many of these manufacturers had attempted to furnish rolls infringing these patents. None of these roller-mills with round corrugated rolls had as yet been introduced into Europe, except in the instance of an occasional isolated machine; but a mill was now being constructed in London on the Stevens roller system. It would seem, in view of these facts, that the conclusions arrived at by Mr. Simon on this point were, to say the least, somewhat premature.

Mr. Wegmann.

Mr. F. WEGMANN, of Zürich, furnished an account by Dr. Sellnick, of Leipzig, of the gradual transformation of his porcelain roller-mills until they had reached their present state of efficiency, explaining the reasons of his advocating the use of porcelain rolls as superior to iron rolls or the burr stone for the advantageous treatment of middlings, for which purpose only his roller-mill was intended. Mr. Wegmann, not approving of fluted rollers for breaking indiscriminately all sorts of wheat, had steadily refused to join in using them. He was persuaded that they would be ultimately given up. The following was an abstract of an article on Wegmann's Porcelain Roller-Mills, by Dr. Sellnick, which appeared in "Mühlenberichte," Nos. 1, 2, 3, 1880–81:—

In the early days of roller milling the method of producing semolina was not considered to have anything to do with the question of roller-mills. The problem attempted to be solved was, how to convert semolina into flour by substituting the crushing action of rollers for the rubbing action of stones. The great importance of porcelain was not at first recognised, as for a long time more stress was erroneously laid on the pressure that the material of the rollers could stand than on the nature of the structure most appropriate for grinding purposes. Although Wegmann had been all along pointing out the particular fitness of his porcelain rolls for the treatment of middlings mixed with bran, as enabling the separation of pure flour from the particles of bran, germ and membrane with the smallest possible pressure, there had been soon also introduced rolls made of chilled iron and steel, which, however, could only be used with the aid of auxiliary machines to disintegrate the product. Messrs. Ganz and Co. of Budapest, at that time constructors of roller-mills under Wegmann's patent, were authorised to adopt chilled iron only from the inability of Wegmann to supply them with porcelain shells in sufficient quantity. Wegmann's porcelain roller-mills have often been blamed for constructional errors and for noisy working, but they had always "ground," and produced from semolina a flour that was strong and baked well. The chilled iron rollers did not make flour unless other machines were called to their aid. Every kind of semolina, whether large or small, whether hard or soft, could and must be ground to flour, and this reduction was performed in the most

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advantageous manner by Wegmann's porcelain roller-mills. When the reduction took place between rollers running with differential velocities, the granules had to conform to the velocity of the quick roller and also to that of the slow roller; this could only happen when half of the granule clung to one roller and half to the other. This clinging required a roller surface capable of seizing hold of the material, and it was clear that smooth metal surfaces were of all the least clinging in their nature, and they were most suitable when it was desired to slide over the material and polish it. The ground porcelain, as used by Mr. Wegmann, possessed in the highest degree the power of adhering; the porcelain had a rough, velvety surface able to detach particles from any body rubbed against it, from a lead pencil to a piece of chilled iron; the latter could be ground on a porcelain roller, not because the porcelain was the hardest, but because of the nature of the surface, which enabled it to grasp and detach minute particles. Nothing showed this dividing and grinding power better than a pencil mark on one of the rollers, which not only rubbed to a complete ring, but was printed off on to the other roller. Mr. Wegmann

Even if the metal rollers were artificially roughened, the porcelain has still the advantage, as the rollers occasionally and unavoidably come into contact, when the surface of the rough metal roller became blunted, but the porcelain only got sharper. Least of all was the required clinging surface present, as had been asserted, in those chilled rollers which had obtained through wear a surface reflecting a dead gloss. The glistening places were polished, and appeared under the microscope as rounded, blunt-edged lumps, large enough to slide over the granules; it was true that the intervening hollows, which did not reflect light and produced the dead appearance, were able under pressure to retain particles, and thence arose the action of these rollers; but this action was in no way analogous to that of porcelain rollers. When examined under the microscope the porcelain appeared to be made up of sharp-angled splintery ramifications, able to retain the smallest as well as the largest particles of semolina without requiring any great amount of pressure, certainly not the excessive pressure under which chilled roller-mills groaned. The porcelain rollers in the first mills constructed by Wegmann were 300 millimetres (11·8 inches) long and 150 millimetres (5·9 inches) in diameter. In order to increase the output and compensate for the small size of these rollers, two pairs were placed side by side in the same frame. Latterly, Wegmann had succeeded in making larger rollers, and the improved Victoria mill had only one pair of rollers 410 millimetres (16·1 inches) long and 350 millimetres (13·8 inches) in diameter.

The most important points about the Victoria Mill were the porcelain rollers, the elastic pressure, the improved feed, and the noiseless gearing. The rollers were cylinders of porcelain of the above dimensions; they were mounted on cast-iron centres. The shaft of the quick-running roller had the driving pulley keyed on to one end, while the other carried the smaller of the two spur-wheels, which transmitted the differential velocity to the slow roller. Many attempts had been made to drive both rollers by belts, but the success had been but moderate, owing to the difficulty of preserving the exact velocities, and also to the excessive pressure produced on the bearings. This method of driving was however now rendered unnecessary by the invention of Wegmann's patent noiseless gearing, which ran perfectly quietly, the only noise heard being a light rumbling of the rollers. The noiseless wheels were made by simply plating up the arms of a spur-wheel and filling the chambers thus formed with small lead shot. The rollers were pressed together in such a manner that they could slightly yield to one another in all directions. The shaft of the quick

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Mr. Wegmann. roller ran in fixed bearings, but the bearings of the other roller shaft were carried by levers hinged below to an elastic support, and connected at the top to a system of spiral springs, by which means the two rollers were pressed together with a moderate pressure, which was kept within definite limits. The feed consisted of two small rollers running in the same direction, a slow-running grooved roller of iron and a quick-running smooth roller of porcelain; these two rollers lay side by side in a shallow tray placed just in front of and below the feeding slit of the hopper. The grooved roller fed the middlings into the space between it and the porcelain roller, which latter picked them up and threw them over in an even shower into the mill. Any bits of iron or foreign substance accidentally mixed with the middlings fell into the shallow tray and could be removed. The output of a Victoria mill varied from about 150 to 200 kilograms per hour, according to the material to be ground, and the percentage of finished product made in the one operation. The rollers wore well; the rollers of six machines which had been running for two and a half years almost day and night in the same flour mill, were still in unexceptional condition; on a few of the rollers there was a slight ridge at the edge about ½ millimetre high, and 1 millimetre broad; this could be easily turned down with a diamond.

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23 May, 1882.

SIR WILLIAM GEORGE ARMSTRONG, C.B., F.R.S., President, in the Chair.

The following Associate Members have been transferred by the Council to the class of

Members.

William Henry Bidder.	Francis Gascoigne Lynde.
Henry Dangerfield.	Walter Parker Smith.
Edward Baudouin Ellice-Clark.	James Strachan.
Albert Chesterfield Jenour.	Robert Wilson.

The following Candidates have been admitted by the Council as

Students.

John Frederick Allan.	William Thomas Lancashire.
George William Butchard.	Thomas Swann.
Frederick Henry English.	Henry James Tilley.
William Erskine Fraser Handcock.	George Herbert Wailes.
Robert Laing.	Arthur Williamson.

The following Candidates were balloted for and duly elected as

Members.

James Gordon Brickenden.	Robert Ring.
Thomas Higham.	Percy Thursby.

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Associate Members.

Richard Armistead.
Thomas Lake Aveling.
Edward Baker.
William Lewis Barrett.
James Herbert Bartlett.
Thomas Broughton.
George William Brown.
John Adye Buchan, Stud. Inst. C.E.
Francis William Chanter, Stud. Inst. C.E.
James Warne Chenhall.
Francis Sheldon Chittenden.
Charles Edward Cooke.
William Tregarthen Douglass, Stud. Inst. C.E.
Henry Joseph Hamp, Stud. Inst. C.E.
Herbert Henderson, Stud. Inst. C.E.
Charles Malcolm Johnson.
Zachary Harris Kingdon, Stud. Inst. C.E.
Edward Rolls Lester.
Charles Augustus Mills.
Francis Orange, Stud. Inst. C.E.
James Orange, Stud. Inst. C.E.
John Frederick Puttick.
George Frederick Ritso.
Charles Edward Winwood Smith.
Charles Edwin Spooner.
Professor James Stuart, M.A., LL.D.
Henry Tyndall Wakefield, Stud. Inst. C.E.
Lawrence Aubrey Wallace, Stud. Inst. C.E.
Beresford Gahan Wallis.

Associate.

Sir David Lionel Salomons, Bart., M.A.

The discussion upon the Papers on "Corn-Mill Machinery," by Messrs. Baker, Simon, and Harding, was continued throughout the evening.

In pursuance of the notice on the Card of the Meetings it was resolved that there should be no meeting on Whitsun Tuesday, May 30th.

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25 May, 1882.

The Session was concluded by a Conversazione, which was given by the President and Lady Armstrong at the South Kensington Museum, by permission of the Lords of the Committee of Council on Education.

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Sect. II.—OTHER SELECTED PAPERS.

(*Paper No. 1754.*)

"Seacombe Ferry Improvement Works."

By Wilfrid Swanwick Boult, and John James Potts, Assoc. MM. Inst. C.E.

From the days when row-boats and river gigs gave place to steamers as a means of communication across the Mersey, up to the year 1857, the landing accommodation at Seacombe consisted of a stone slip 15 feet wide, built on the foreshore on an incline of 1 in 20. Fixed along this slip were railway metals, for carrying a movable stage, which was allowed to run down by its own weight as the tide ebbed, and was hauled up by steam power winding in an attached chain on the flood tide. By this somewhat primitive arrangement the deck of the movable stage was constantly kept at a suitable height for embarking and landing the passenger and goods traffic of the ferry steamers. In 1857, owing to a greatly increased traffic, it was found necessary to provide additional accommodation. This was done by widening the slip and stage to 21 feet, but the previous system of landing was maintained.

The annual passenger traffic having reached to about one million and three-quarters, it became evident that a ferry on a totally different scale was an absolute necessity. After several years spent in discussion, and after many designs had been submitted in competition, the plans of Mr. W. Carson, M. Inst. C.E., were adopted by the Wallasey Local Board, to whom the ferry belongs, and the Mersey Docks and Harbour Board, and were embodied in the Wallasey Improvement Act of 1872, by which it was settled that the incidental reclamation of foreshore should be carried out by these two Boards conjointly, the cost to be defrayed in proportion to the area of reclaimed land which each retained. The first contract, that for the river wall, was let in May 1876.

General Description.—(Plate 9, Fig. 1.)

The old slip was laid across a triangular piece of foreshore, bounded on one side by the north wall of the "North Reserve," belonging to the Dock Board, and on another by the Marine Parade,

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a sea wall skirting private property; while the third side was open to the river. Along this third side a wall has now been built, upwards of 1,000 feet in length, extending from the shipbuilding yard on the south to Seacombe Point on the north. The land so enclosed amounts to nearly 4 acres, about two-thirds of the filling for which was obtained by levelling down the high bank forming the bowling green and grounds of the old Seacombe Hotel, and a field beyond. Of this area nearly one-half (8,395 square yards) has been taken by the Dock Board, who thereby obtain a nearly rectangular plot with a deep-water frontage, eminently suitable for a shipbuilding yard or similar purpose, in place of an awkwardly-shaped triangular area with no river frontage. The remainder of this reclaimed area is occupied by the approaches and accessories to the ferry, and by the owners of private property adjoining.

Moored to the new wall, at a clear distance at low water of 226 feet 9 inches from the coping line, is a floating landing-stage of similar construction to the great Liverpool stage. Communication with the land is maintained by two bridges of 160 feet span, attached to cylinder piers, which project 80 feet from the river wall. Considering the hard nature of the ground and the large amount of dredging that would have been required in the first instance to provide sufficient depth of water for the landing-stage, if fixed without the interposition of piers, and, in the next place, to ensure a straight course for the tide to maintain the necessary depth, it was decided to extend the stage considerably into the river, and so reduce the dredging to a minimum. As the Seacombe Ferry is situated just at the narrowest part of the Mersey, where the tide sometimes runs at 6¼ knots an hour, with a maximum rise and fall of 32 feet 6 inches, it was not deemed prudent, nor would it have been permitted by the Conservancy, to encroach on the fairway of the river further than has been done, and the length of the bridge piers was fixed at 80 feet, although this was not sufficient to obviate entirely the necessity for dredging. It had been determined by the Local Board to provide not only for passenger and ordinary cart traffic, but also for loaded railway wagons, in the hope that the Dock Board might thereby be induced to organise suitable accommodation for this class of traffic on the Liverpool side, and so connect the dock systems on both sides of the river. This object has been attained in the following manner (Fig. 2):—Between the two bridge piers a high-level pier is carried out as far as the landing-stage, and has at its outer end two hydraulic lifts capable of transferring loaded railway wagons bodily between the landing-stage and pier. In connection with the lifts rails are

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laid on the landing-stage and along the high-level pier, and joined with the dock system of railways.

The spaces between the bridge piers and the high-level pier are filled in by platforms, forming with the piers a floor, on which buildings for the accommodation of the passenger traffic partly stand, being also continued for 29 feet on to the quay. The primary object, however, of the platform is not so much to support the buildings as to connect the piers together and bind them into one continuous whole, so as to be better able to bear the stresses induced by the motion of the bridges, and to oppose a greater resistance to vessels that may run foul of it. The long projecting high-level pier is protected by the landing-stage and bridges. An engine- and boiler-house and accumulator-tower are built in a convenient position contiguous to the passenger buildings.

A main approach road to the Ferry Station, 122 feet wide, has also been constructed over the reclaimed land. Simultaneously with the execution of the above works several of the roads in the neighbourhood leading to the ferry were widened, and had their gradients eased under the direction of the Board's Surveyor, Mr. James T. Lea.

Temporary Landing-Stage.

A short distance south of the old Seacombe Ferry a vacant shipbuilding yard was obtained for an approach to the river during the execution of the works, which absorbed the old ferry site, advantage being taken of the existence of a large shed, under which carriages could be driven and a cabstand be established. The temporary landing was arranged with a floating stage and bridge, which had previously done duty at the "South End" Ferry on the other side of the river.

The floating stage was formed with one pontoon of wrought-iron plates $\frac{1}{4}$ inch thick, 120 feet by 30 feet, by 7 feet 9 inches deep in the frame, with a projection under the bridge 20 feet by 10 feet: the whole was stiffened with angle-iron frames, bulkheads, and flooring plates. The deck was of 3-inch pitch pine, and had a camber of 7 inches. The moorings were $1\frac{3}{4}$-inch chains.

The bridge had a span of 150 feet, and, although it acted as a boom to resist the pull of the mooring-chains, and to take up the roll of the stage in rough weather, it was of very light construction. There were two plate girders of the bowstring shape 8 feet apart in the clear, 152 feet long by 7 feet 6 inches deep in the centre. The roadway was attached to the bottom flanges.

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The old shipbuilding yard through which the ferry was to be approached, sloped down to the river wall, where the level was 14 feet 6 inches above the Old Dock Sill, Liverpool, which is the datum level always employed on the banks of the Mersey, and is 5 feet below Ordnance datum. This being too low for attaching the bridge, a timber pier 16 feet wide was carried out from the ground at the back, 24 feet above datum, to within 35 feet of the river wall. On this pier the inshore end of the bridge was hinged to a crosshead, which latter was capable of motion in a horizontal direction round a centre pivot. The connection with the landing stage was of the same nature.

As at low water of spring-tides the stage took the ground, to guard it against injury five balks of timber were fixed to the bottom. A landing-boat, carrying a platform 50 feet by 8 feet 6 inches, was at such times moored end-on to the outside of the stage, and reached into sufficiently deep water for the ferry steamers to come alongside.

River Wall.—(Plate 9, Figs. 3 to 7.)

The river wall, extending from the North Reserve to Seacombe Point, presents few features of special interest. Borings had shown that for its whole length it would rest on a thick bed of very hard boulder clay.

The wall is built of random soft-stone masonry in hydraulic lime mortar; the face being formed of broken coursed, pitched faced stones, and pointed with Roman cement. The proportion of large stones was high, two-thirds of the masonry being in blocks of not less than 20 cubic feet each. The mortar was prepared and supplied to the contractor by the Mersey Docks and Harbour Board, and was at first made of 3½ parts by measure of lime to 5½ parts of sand; but these proportions were soon altered to 4 parts of lime to 5 parts of sand, which withstood the action of the tide on unfinished parts much more satisfactorily. The limestone, as usual on the dock estate, came from the Halkin mountain, in Flintshire.

Work was commenced by driving piles for the staging necessary for two steam-jennies, which were employed during the construction of the wall. The uprights, 14 inches square, were spaced 20 feet apart from centre to centre, and double running logs of the same scantling, bolted together in 40-feet lengths, so as to break joint, were dogged on the top, the butt joints of the lower runner resting on corbels, and being further secured by cheeks

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bolted to the upright and runners. Opposite every alternate upright a spur pile was driven, and a half-balk brace bolted to both. The jennies were mounted as "Goliaths," their span being 58 feet 6 inches, and they were each capable of lifting 10 tons.

At the south end of the wall a well 12 feet square was sunk to a depth of 10 feet below the foundation level, and securely timbered. A box lander, 1 foot 6 inches by 1 foot 3 inches, connected the well and the foundation hole, and was continued under the wall as the work progressed. A blow-lander of similar construction was led directly through the wall at a level just deep enough to allow the holes to be flooded before the tide poured in over the sides. A Murray's chain-pump, with feathering buckets, 3 feet by 1 foot, was fixed in the well, and gave great satisfaction, never having required the slightest repair during the ten months it was in use. It was driven by a belt from a locomotive engine. With this machinery a hole 65 feet by 17 feet by 10 feet, containing 68,980 gallons of water could be emptied in fifteen minutes, or at the rate of 4,600 gallons per minute.

The wall was founded throughout its entire length at a depth of 10 feet at the toe, and 10 feet 8 inches at the back, below Old Dock Sill. Opposite the piers it is carried up to a height of 27 feet, and for the remaining portion terminates at 24 feet, above this datum. For the greater part of its length the foreshore was at about the datum level; at the south end it was 6 feet below, and at the north end 2 feet above. For a foundation nothing better could be desired than the hard boulder clay in which the wall stands. So hard and solid is it that no sheet piling or timbering of any sort was required; the sides of the holes standing nearly vertical (with a batter of 6 inches) for a depth of 10 or 11 feet, even though, as sometimes happened through attempting to level up too large an amount of work in one tide, the hole was to a great extent filled with water over the edges, instead of its being let quietly in by the blow-lander, well, and emptying lander. The object of leaving the work as smooth and even as possible at the end of each tide was twofold. First to reduce the chance of the mortar being washed out of the joints, and secondly to minimise the deposit of silt and allow of the easy removal of what found its way on to the work. The amount of this deposit was, in rough weather, considerable. After two tides 36 cubic yards of silt have been removed from a length of 60 feet of wall; the setters and wallers meanwhile waiting till they could get to work. This operation occupied twenty-three navvies and a steam jenny for one hour and a quarter, out of a total working time of three hours and forty

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minutes—that is, for one-third of the tide. Overlying the clay was a bed of sand and gravel, constantly varying in depth as it was drifted by the waves, but averaging between 2 and 3 feet thick. To keep this out of the open holes, a row of blocks of ashlar and backing was sunk through it on to the clay. This proved convenient and inexpensive, as, when the work had been brought up to the level of the foreshore, the stones, being no longer required to keep out the sand, could be carried on for use in the next hole as soon as the clay there had been laid bare. The clay being too hard for lunching, was got with picks. A gang of twenty-six men could excavate and fill into skips 32 cubic yards in a tide, or at the rate of 1¼ cubic yard per man per tide. When work was in full progress, the foundation was put in in lengths of from 60 to 70 feet. The best five weeks' work was done from the 27th of July to the 31st of August, 1877, when three holes, averaging 62 feet 4 inches long, were excavated through 10 feet 3 inches of clay, besides about 18 inches of sand and gravel, and the whole filled with concrete and masonry to a level of 2 feet above Old Dock Sill. Altogether four hundred and seventy-one tides were occupied in founding this wall.

The details of construction were as follows: A hole having been excavated to foundation level, the bottom was covered to a depth of 2 feet with concrete composed of 8 parts of shingle, gravel, and sand, from the beach, to 1 part of Portland cement. In this concrete, burrs were embedded, care being taken that no two were allowed to touch. On the concrete, blocks of backing and old masonry from 2 to 3 feet thick were set in mortar, leaving spaces of from 6 inches to 2 feet between them, which were filled indiscriminately with either concrete or rubble masonry. Above this foundation course the wall is built in mortar. The coping stones are joggled together and well bonded into the work below, experience in similar situations having shown this to be a necessary precaution.

Immediately to the south of the goods' bridge pier is a flight of granite steps, 7 feet wide, built of large blocks, two steps in each.

The cast-iron bed-plates on which the girders of the bridge piers rest, and to the back of which they are secured, are in their turn bolted down with 2-inch Lewis bolts to blocks of granite, 2 feet thick by 5 feet deep, and anchored to masses of concrete at the back of the wall by twelve 2-inch anchor bolts of 28 feet average length to each pier. The bolts are disposed in two similar tiers of six each, and splayed out at the back like a fan. The in-shore

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ends are enlarged to 2¼ inches in diameter, and are screwed. Cast-iron washer-plates, 4 feet by 2 feet, are passed over the ends, one plate taking the two corresponding bolts in the two tiers.

Provision for attaching the mooring chains of the landing-stage, which are arranged in two groups of two each, is made as follows: At a distance of 16 feet behind, and 10 feet 6 inches below the coping, mooring bollards are built into extensions of the wall. A circular wall is carried up round each bollard, forming a chamber 7 feet in diameter, the work being gathered in above up to the quay level, so as to leave a man-way 2 feet in diameter. From each chamber a hawse-hole leads to the face of the wall, where the two forming one group are united in a cast-iron hawse-pipe.

The wall is backed up for a width of 24 feet from the face with rock rubbish, which was gently poured out of the wagons in which it came by the steam-jennies, and the filling behind is principally clay from the adjoining ground.

Bridge Piers.—(Plate 9, Fig. 2.)

The piers for supporting the shore ends of the two bridges are alike, and extend 80 feet from the river wall; they consist at their outshore ends of six columns, sunk about 14 feet into the foreshore, composed of cast-iron cylinders, 5 feet in diameter by 1¼ inch thick above the foreshore level, and 6 feet 6 inches in diameter, by 1⅛ inch thick below, put together in 5-feet lengths. A taper length, also 5 feet long by 1½ inch thick, connects the upper and lower lengths of the column. The ends of all the cylinders are machine-faced, and are connected together by bolts 1 inch in diameter, through internal flanges supported by brackets. After erection these columns were filled with Portland cement concrete. The caps to the columns have brackets, on to which are bolted heavy strut castings. These struts are of a box form, 2 feet deep, and the same width as the wrought-iron girders which rest upon them, and which communicate the pull of the stage to the anchorages.

The six columns in each pier-head are bound together at 24 feet above datum, and connected with the river wall, by three lines of wrought-iron double-web girders, all 3 feet deep. The centre girder is 3 feet, and the outer ones are 2 feet wide, and they are attached to bed-plates on the wall as previously described. They are stiffened by single-web cross-girders at intervals of about 15 feet, and by two box-girders over the columns.

Midway between each pier-head and the river wall, the main

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girders are supported by cast-iron columns, 18 inches in diameter, similar to those for the high-level pier, and braced in the same manner.

On the tops of these wrought-iron box-girders, plates $\frac{5}{16}$-inch thick, with corrugations 5 inches deep and 16 inches from centre to centre, are laid; the ends overhang the outer girder to take a fascia plate. They are riveted to the girders in each furrow, and to each other at all laps, with rivets $\frac{3}{4}$ inch in diameter and 3 inches pitch. Down the centre of the south, or goods' bridge pier, a cart-track is formed similar to those on the high-level pier, except that there are no rails for wagon traffic. The remainder of the surface of the pier, and also that on the north, or passenger bridge pier, under the station, is ballasted to a depth of 2 inches over the ridges of the corrugated plates with Portland cement concrete, upon which Brunswick rock asphalt 1 inch thick is laid.

On the outer side of each pier-head a cast-iron entablature, 4 feet 3 inches high, is fixed; and on the outer side of the south bridge pier, a fence similar to that on the high-level pier is carried from the entablature to the fence wall on the quay.

HIGH-LEVEL PIER.—(Plate 9, Figs. 2, 8, 9; and Plate 10, Figs. 10 to 12.)

The high-level pier, for cart and horse and wagon traffic, extending from the river wall to the inshore side of the landing-stage, is midway between the bridge piers, and is formed at its outer end of four columns, 5 feet in diameter, sunk about 12 feet 6 inches into the foreshore, similar to those for the bridge piers, except that there are no strut castings between the column heads, and that each cylinder length has a bracket cast on it, to which are bolted in 10-feet lengths the cast-iron vertical guides for lift platforms. There are also two intermediate columns, composed of cylinders 2 feet 6 inches in diameter and 1 inch thick above the surface of the foreshore, and 4 feet in diameter and $1\frac{1}{8}$ inch thick below, in 5-feet lengths, with a taper-piece 1 foot long, $1\frac{1}{4}$ inch thick, connecting the upper and lower lengths, also having brackets 5 feet apart for an attachment for the vertical guides. The outer three columns, in addition to the vertical guides, have radial guides fastened to them in the same manner. These columns are also all filled with Portland cement concrete.

The tops of the columns are connected together by wrought-iron double-web girders 3 feet deep and 2 feet wide, except at the landing-stage side, which is left open to allow the wagons, etc.,

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to be taken off when the stage approaches the level of the roadway on the pier. The roadway of the pier between the columns and the river wall is supported by three lines of wrought-iron single-web plate girders, 10 feet apart from centre to centre, and 3 feet deep, with flanges 15 inches wide, connected by cross-girders formed of a web plate and double angle-irons, in line with each transverse row of columns.

The main girders are supported at intervals of 29 feet 3 inches by cast-iron columns, 18 inches in diameter by 1 inch thick, cast in four pieces. The bottom lengths, which are sunk about 6 feet into the clay of the foreshore, have screw blades at the bottom, and sockets at the top into which the next lengths are inserted, having no flange on their lower ends. They, and the upper lengths, are bolted together through machine-faced flanges. The caps, with a 3-feet length of bearing for the girders, sit on a machined shoulder on the upper length. These, and all the other 18-inch columns, are braced with channel irons attached to brackets cast on the columns, and were filled with Portland cement concrete up to 1 foot above the flange joint, or 10 feet above datum, before the caps were put in place. At their landward ends the roadway girders rest upon and are secured to the cast-iron wall-plates.

On the tops of the girders corrugated plates, of the same dimensions as those for the bridge piers, are riveted in two lengths in the width of the pier deck, having a butt-joint made on the centre girder. The ends overhang the outer girders and form a footwalk on each side, to which cast-iron cantilevers are carried up from each column head. The extreme width of the pier deck is 29 feet. Upon these plates, at 4 feet 8½ inches gauge, a double line of bridge rails, weighing 60 lbs. to the yard, is laid along the whole length of the pier, riveted to each corrugation with ¾-inch rivets. Cast-iron wheel-guards, standing 4 inches above the deck, are bolted at the sides of each cart track. The remainder of the surface is formed of greenheart timber 3 inches thick, in 6-inch widths, running longitudinally, laid close and secured to the corrugated plates at every fourth corrugation with galvanised deck bolts, ⅝ inch in diameter, and afterwards caulked. A horse track, 4 feet wide, is formed in the centre of each line of rails with greenheart sheathing 1½ inch thick, in 4-inch widths, laid transversely and secured to the planking with galvanised ragged spikes. The wheel tracks are served with flat bars of wrought iron, 3 inches by ½ inch thick. Scupper holes are left in the deck 12 feet apart.

A cast-iron entablature is fixed at each side of the pier-head,

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and a standard carrying three lamps is mounted over each 5-feet column. From this entablature, down each side of the pier, a fence 3 feet 9 inches high is formed of cast-iron standards, 5 feet 10 inches apart, carrying three rails, the top rail being of strong steam pipe, 2½ inches in diameter; the two others are solid wrought-iron bars, 1½ inch in diameter. Lamps, with copper frames fixed on standards immediately over each 18-inch column, are incorporated with, and form part of the fence, the top rail of which is used as the gas-service to the lamps.

Protecting Cylinders for Hydraulic Lift Cylinders.—(Plate 9, Fig. 8.)

The two protecting cylinders in the centre of each line of rails, which are 12 feet 3 inches apart, and midway between the centres of the 5-feet columns at the high-level pier-head, forming wells in which the two ram cylinders for working the platform lifts are placed, are 5 feet in external diameter, in 5-feet lengths by 1¼ inch thick. They are sunk to a depth of 50 feet 8 inches and 53 feet 8 inches respectively below datum, or 40 feet 2 inches and 43 feet 2 inches below the river-bed. The bottom of each cylinder is filled with strong Portland cement concrete, upon which the bed-plates for the ram cylinders were solidly bedded before it had set. The top lengths, which are about low-water level, are 1 foot deep, and have a stuffing-box with gland, through which the rams attached to the lifts pass, and are made watertight with gasket-packing.

Manways, 3 feet by 2 feet 6 inches, are left in the top 5-feet lengths of the cylinders, immediately under the lengths carrying the stuffing-boxes, and access is obtained from the surface of the pier by a cast-iron column 2 feet 6 inches in diameter, 1 inch thick, in 5-feet lengths, which terminates in an oblong cast-iron tube 3 feet 6 inches by 2 feet 6 inches by 1⅛ inch thick, leading to the protecting cylinders, and bolted at the ends through flanges to the manway openings; these have similar flanges, and the joints are caulked with rust cement. The top length has a hinged door of wrought iron, allowing access to the ladder, which is secured to the inside of the tube, and extends down to the connecting piece.

Hydraulic Lifts.—(Plate 9, Figs. 2, 8, 9.)

The rams and ram-cylinders for actuating the two platforms are of cast iron. The former are 40 feet long, each with a square

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head and flange to fit into the centre cross-girder of the platform, and cast on end in one piece; they are 14 inches in diameter, and allow of a maximum stroke of 32 feet 9 inches, which is about 1½ inch more than the distance from the level of the roadway of the pier to the level of the deck of the landing-stage at the lowest tide. The ram-cylinders were cast in two lengths, and are bolted together through flanges, and erected upon the cast-iron bedplates, 4 feet in diameter, in the protecting cylinders.

Each platform, which is 23 feet long by 9 feet 9 inches wide over the guide blocks, is composed of two wrought-iron solid web-girders longitudinally, formed of plates and angle-irons stiffened with T-irons, connected transversely by seven solid web-girders, also of wrought iron. The centre cross-girder is of varying depth, to allow the full stroke over the top of the protecting cylinder, and has double webs, between which the ram-head is secured. Guide blocks of cast-iron are bolted to the top and bottom of each end of each side girder, and work within the vertical guides.

Each lift platform carries a movable floor 28 feet long by 8 feet 5 inches wide, capable of motion in the direction of its length, composed of two solid web-girders 12 inches deep, stiffened with single-web cross-girders 4 feet apart.

In order to afford the necessary connection between the landing-stage and the platform in the varying positions they occupy at the different tide-levels, and to avoid the use of movable gangways, the two longitudinal girders of the movable floors are prolonged 5 feet beyond the lift platform, and have secured to them cast-iron guide blocks, fixed on the ends of a through shaft of wrought-iron, which work within the cast-iron radial guides, whose curvature has the same radius as the span of the bridges which connect the landing-stage with the piers. Rubbing pieces of cast iron are fixed between the platform lift and the movable floor. A line of bridge rails is laid upon the longitudinal girders of each movable roadway, and the roadways are similar to that on the high-level pier; the outer sides of the cast-iron kerbs to the cart-track bear against cast-iron blocks bolted to the insides of the platform girders.

The lifts are controlled by valves of gun-metal placed in a hut on the pier-head adjacent. The ram-cylinders are also connected together, so that advantage can be taken of a descending load. And in order that they shall not overrun their stroke, automatic check gear is fitted to each lift to control the varying stroke between the pier and the landing-stage at any state of the tide.

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A wrought-iron square bar laid along the deck of the lift inside the cast-iron kerb is pushed back by a roller on the stage when the lift gets to the bottom of its stroke, causing it to shorten a chain which is attached by levers to the valve-handle, thereby closing the exhaust valve; when the platform reaches the top of its stroke it strikes against a lever which shuts off the pressure. The longitudinal travel of the movable roadway between the level of the pier deck and the landing-stage deck at lowest tide is 3 feet 1 inch, being the distance which the landing-stage is drawn in by the bridges. Two bolts are projected into the inshore end of each movable roadway as soon as it arrives at the top of its stroke, to take the jar of heavy weights passing on and off the platforms; the levers for working the bolts lock the levers of the valves.

Platforms between the Piers.—(Plate 9, Fig. 2, and Plate 10, Figs. 10 to 12.)

The high-level pier and the bridge piers are connected together and formed into a solid platform to a distance from the river wall equal to the length of the latter. The floor of the platforms is composed of asphalt upon Portland cement concrete, laid on wrought-iron corrugated plates in the same way as on the bridge piers, and is carried by three lines of wrought-iron single solid web-girders, 13 feet 5¼ inches from centre to centre, stiffened with single web cross-girders over the 18-inch supporting columns, which are like those in the high-level pier. The inshore ends of the girders rest on cast-iron plates on the river wall. A guard fence, similar to that on the high-level pier, is fixed on the river side, and a cast-iron fascia plate is bolted on the outer girder.

Weight of the Floor per square yard.

	lbs.
Brunswick rock asphalt, 1 inch thick	112·50
Portland cement concrete, 2 inches over the plates .	425·25
Wrought-iron corrugated plates, $\frac{1}{8}$ inch thick . .	162·25
	700·00

Erection of the Piers and Platforms.

For the erection of the piers a temporary timber staging was constructed of sawn pitch-pine. It extended over all the columns except the inshore row, for putting in which half balks were

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thrown across from the staging to the river wall. Piles 10 inches to 12 inches square (which formed the lower part of the uprights), having cast-iron shoes of 24 lbs. weight, were driven, at intervals of 15 feet, about 6 feet into the ground by an ordinary derrick machine, mounted upon a river-flat dismasted and covered with a rectangular platform for this purpose. The monkey, which was wound up by hand, weighed 17 cwt., and the average fall was about 15 feet, when one blow was delivered in two minutes, with six men at the winch. At a depth of 5 feet the piles went down $1\frac{3}{4}$ inch per blow. The flat was grounded for working, and two piles were driven per tide, and the whole number were put in in two months. The bracing of half balks was fixed with 1-inch bolts and $\frac{5}{8}$-inch dogs. At a level of 31 feet 6 inches above Old Dock Sill, a deck was formed of 3-inch planks on half-balk joists, and on this were laid two lines of rails, of 4 feet $8\frac{1}{2}$ inches gauge, one down the centre of the high-level pier, and the other at right angles to this and extending between the two bridge piers. At their intersection the lines were connected by a turntable, and were used by a steam crane and a few lorries. After the columns had been erected and filled with concrete, the staging was cut down to 23 feet above datum for convenience in erecting the girders.

The engineer had designed the 18-inch columns to stand on an enlarged base, which was to be planted in the ground, a hole being dug out for this purpose. The contractors, however, hoping to be more independent of the tide, preferred the use of screw piles, and after a warning from the engineer of the unnecessary difficulties they were about voluntarily to encounter, they were allowed to have their own way. In view of the strong run of the tide, and its consequent great scouring action at this part of the river, the piles were sunk to an average depth of 5 feet 3 inches into the clay, or 6 feet 3 inches into the foreshore. A greater depth than this would have been impracticable with the method of sinking adopted, and, all things considered, was unnecessary.

Several designs of piles having been experimented with in the course of the work, it will be convenient to enumerate them in order. No. 1 pile was a plain hollow cylinder, 18 inches external diameter, and of metal $1\frac{1}{4}$ inch thick, terminating at its upper end (as in all the other designs) in a socket for the reception of the upper portion of the column; at its lower end it finished in a sharp cutting edge formed by splaying off the outside. Cast in a piece with this was the screw blade, 3 feet 6 inches in diameter by $2\frac{1}{4}$ inches thick at the base, tapering to $\frac{1}{2}$ inch at the periphery.

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There was one complete turn to this section, the blade then gradually dying out. The dimensions were:—

	Feet.	Inches.
Length of pile	9	3
Length of socket	1	5
Diameter of screw	3	6
Pitch of screw	0	7
	lbs.	
Weight	2,660	

No. 2 was in all respects similar to No. 1, except that the bottom of the barrel was formed into four teeth, 3 inches deep. In No. 3 was another modification of the bottom, the end being closed with a loose auger point 2 feet 9 inches long. In No. 4 a new principle was introduced, the pile being cast with a taper inside, so that the clay might pass freely up as the pile was screwed in. In other respects it was like No. 2. The only difference between No. 4 and No. 5 was that the latter had the edge of the screw-blade serrated, so as to resemble a circular saw with gigantic teeth. The diameter of the screw-blade was in No. 6 reduced to 2 feet 10 inches. There were two blades at 10 inches pitch, each extending to about one-third of a circle. In No. 7 the blades were increased to half a turn each. Otherwise this and No. 6 were alike. Three alterations were introduced in No. 8. The diameter of the blades was reduced to 2 feet 6 inches, the pitch was increased to 18 inches, and the end, being left open, was fitted with an auger point 10½ inches long, cast separate, riveted on and run with lead. The pitch was again reduced to 10 inches in No. 9, which was otherwise similar to No. 8. Practically No. 10 was similar to No. 9, the only difference being that the pitch of the former was 9 inches instead of 10 inches.

The capstan first used consisted of ten hickory bars of 4½ inches by 4 inches section shod at their outer ends with deeply grooved castings to take the rope, and connected at the centre by a cast-iron body which fitted inside the socket of the pile, and was prevented from turning in it by two steel pins 1⅜ inch in diameter, placed at right angles to each other and running completely through. The diameter of the capstan was 18 feet. To assist in distributing the strain evenly over the bars, the shoes were connected together by light chains. These bars proved too weak for the work, and a new set had to be provided. They were made tapering from 6 inches by 6 inches to 5 inches by 5 inches; the proportionate strength of the old to the new thus being as 3 to 8. The diameter of the capstan was kept at 18 feet, that of the body

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being 3 feet 6 inches. This second capstan stood perfectly up to the end of the work.

A 4-inch hemp rope was at first used for turning the capstan, but after having several times parted, a 6-inch rope was substituted for it.

The crabs could be worked with either single or double purchase. In the former case the throw of the crank-handle was 32 inches; the pinion had twelve teeth in gear with a spur wheel with seventy-eight teeth on the barrel shaft; the diameter of the barrel was 7 inches. The strain on the rope was thus $\frac{32 \times 78}{7 \times 12} = 29{\cdot}7$, or say thirty times the power put into the handles. Taking the force exerted by one man at the moderate amount of 20 lbs., this makes for each crab driven by the usual number of five men a total pull of 3,000 lbs., which, acting 9 feet from the centre of the pile, gives a twisting moment of 12·2 foot-tons, or for the two crabs 24·4 foot-tons. This stress was of course often largely exceeded. The double purchase of a little over five times the single, was only used in extreme cases. On one occasion, only one pin having been put in for turning the pile, it was shorn through in two places at once. The pin being of steel, and $1\frac{3}{8}$ inch in diameter, this, taking the shearing strength at 30 tons per square inch, represents a force of 90 tons, acting at 10 inches from the centre, or $8\frac{1}{2}$ tons at the ends of the capstan bars, equal to a moment of 75 foot-tons.

Work was commenced on the 17th of April, 1877, a makeshift guide being used consisting of two whole balk-uprights connected by a transverse beam to which the pile was held by a timber cap bolted on with distance pieces between. The two crabs were placed on the beach, and lashed down to heavy stakes at opposite sides of the pile. The design of pile was No. 1. With this pile commenced a series of troubles destined to last over many months. It soon became evident that to attempt to screw it into the solid clay was a hopeless task. As a foretaste, also, of what would have to be provided against, one morning the men arriving on the ground discovered that the timber uprights, which reached down, through 18 inches of sand, 3 feet into the clay, had been washed out and carried away by the tide; the pile being left prostrate on the beach. At a depth of 2 feet 6 inches in the clay, the pile refused to go down, although there was no difficulty in turning it. It being supposed that the obstruction must be a large boulder, a pointed bar was driven down inside the pile as far as it would go, and then worked about until loose, and when dropped to the bottom the sound of stone was clearly audible.

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The pile was then dug out and the boulder vainly looked for in the excavation. On examining the pile, however, the obstruction was discovered; the bottom being solidly plugged up with clay so hard and firmly wedged in that it could only be cleared out with picks. Embedded in this was the "boulder," about the size of a cricket-ball, with marks of the pointed bar upon it. The pile had been loaded with between 5 and 6 tons of pig-iron whilst being rotated. A slightly modified form of pile, No. 2, was next placed in the hole from which No. 1 had been dug out. After a great deal of trouble, and increasing the load on the top to 8 tons, a total depth into the clay of 5 feet 3 inches was reached, the pile having gone in the last eight turns only $1\frac{1}{2}$ inch or $\frac{3}{16}$ inch per revolution. It was now necessary to miser out the core of clay left standing inside the pile. After between two and three tides' work this was done, and the pile screwed down to the required depth. Removing the clay in this way was very tedious work; two men could do little more than scrape it out; the thin shavings brought up being hardly thicker than paper. A trial was next made with a solid-point pile, No. 3. This, however, was soon given up as a failure, and another pile put in its place. No. 4 worked better than the previous ones; but this is all that can be said for it. When it had been got down, this part of the work was suspended pending the erection of the temporary timber staging. On its completion, the piles were screwed from the staging deck so as to render the work as independent as possible of the tide. Special screwing pieces had, of course, to be cast. They were first made 18 inches in external diameter and of 1-inch metal in the barrel, being reduced at the lower end to 16 inches in diameter with $1\frac{1}{4}$-inch metal. Two such lengths were fitted together as a continuous column 18 inches in diameter without projection of any kind to be in the way of the guides. To prevent rotation at the joint, the socket end of the lower length had two internal lugs fitting into corresponding recesses in the spigot of the upper piece. Inside the upper of these two lengths was a third one capable of adjustment as to level by holes, through which steel pins were passed to form the connection at the required height. Thus the capstan head could always be kept at a convenient level for working. Lugs, instead of pins, were used for attaching the pile to the screwing piece, as it was not then necessary to wait for low water to disconnect them. These first screwing pieces proved too weak; they shivered at all the joints, from bottom to top, over the first pile on which they were tried. A second set was then cast of the following dimensions:—Diameter

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of barrel 18 inches, thickness of metal 1½ inch, diameter of the spigot 15½ inches, thickness of metal 2 inches.

The attempt to screw piles into the solid clay proving tedious work, it was determined to have recourse to blasting, and on the 23rd of November, 1877, the first shot was fired. The charge was 2 lbs. of powder lodged 6 feet into the clay. The effect of this small shot was not much; the tamping was blown out and the ground slightly shaken. The next day another shot of 3½ lbs. of powder was fired on the site of another pile with better results. A day or two afterwards a pile was pitched and the work of screwing begun. The pile had a double thread at 10 inches pitch, and went down in the first turn 14½ inches. The cut then steadily diminished till, at 3 feet 10½ inches in the ground, or about 2 feet 6 inches in the clay, it refused to go any lower although there was no difficulty in turning it. The next morning a couple of cast-iron cylinders, 6 feet 6 inches in diameter by 5 feet long, and weighing nearly 3 tons each, were put on the top of the capstan. They had the effect of making the pile bite at once and go in 7 inches per revolution. One of the cylinders was then removed, reducing the cut to 5 inches. The second cylinder was after a few turns taken off to ease the tackle, on which there was a great stress. The cut then gradually decreased to 1½ inch as the pile reached the required depth, going very stiffly. This was the first pile got down without misering out the core. One more attempt was made to do without blasting with a pile of No. 8 design with the following result:—After penetrating the sand and gravel it went into the clay for three revolutions at the uniform rate of 8½ inches per revolution. It was then left until the next day, when it went down 12 inches in one turn, at which point the driving lugs were carried away. This damage having been repaired, on again attempting to turn the pile it broke in two, twisting off through the lug rivet-holes. After this experience blasting was regularly employed, the charge being 5 lbs. per shot, and one shot to each pile. With this assistance the piles were all got down, and by the end of April, 1878, twelve months after the first pile was pitched, the whole forty-two were in place. Altogether four piles were broken whilst being screwed in.

On the 27th of September, 1877, the cylinder sinking was begun. The twelve cylinders in the bridge piers presented no particular difficulties, as the foreshore at those points was frequently left by the tide for from two to four hours at a time. They were 6 feet 8 inches in extreme diameter for a height of 6 inches from the bottom to leave clearance for sinking, and finished

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with a cutting edge. These cylinders were sunk to an average depth of 14 feet into the foreshore, or 13 feet into the clay. When the gravel and sand on the surface had been penetrated the cylinder soon made a watertight joint with the clay; after it had entered this stratum about 5 feet, work could generally be continued at all states of the tide. The gang at each cylinder consisted of four men. Once or twice, however, the tide found its way in after all was supposed to be tight. The site of the high-level pier cylinders, however, seldom or never dried, and it was found necessary to have recourse to air-pressure to exclude the water. A cast-iron plate 8 feet square by 2½ inches thick, weighing 50 cwt., having been faced up on the lathe, was bolted on the top of the cylinder to be sunk, the joint being made with red lead, and was loaded with pig-iron. In this plate the air-lock was fitted. The air-pumps had two cylinders 12 inches in diameter by 18 inches stroke, side by side in a cast-iron tank, through which a stream of cold water was kept running when the pumps were at work. The average speed was twenty-four revolutions per minute. The suction and delivery pipes were both 3 inches in diameter. The power was taken through a belt from a portable steam-engine and boiler combined. The engine had one cylinder 8 inches in diameter by 9¾ inches stroke, and ran at a speed of eighty revolutions per minute. A pressure of from 75 lbs. to 80 lbs. per square inch in the boiler could maintain an air-pressure of 30 lbs. per square inch, this being greater than was required, except in the case of the two protecting cylinders for the hydraulic-lift cylinders in which a maximum of 36 lbs. per square inch was reached. The spoil was hauled up by a small hand-winch fixed on top of the air-lock plate, with a wire rope running through a stuffing-box. Three men were engaged inside at a time, two getting and filling, and one man above to pass the buckets through the air-lock. The capacity of the buckets was 3 cubic feet. No special difficulties were encountered in sinking the pier-cylinders, the air-pressure being moderate and the clay being a comparatively easy material to deal with. But the protecting cylinders for the hydraulic-lift cylinders gave considerable trouble; not only was the depth much greater, necessitating a correspondingly increased air-pressure, but the clay was soon left, and, after passing through a bed of sand 5 feet 6 inches thick, the solid sandstone rock was encountered and had to be sunk through for about 20 feet. Under the circumstances blasting was inadmissible, and the rock had to be excavated with picks, wedges, and hammers; and this, partly owing to the cramped space, was slow work, though kept at continuously night

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and day, which was not the case while sinking through clay. Another cause of delay in these deep cylinders was the necessity of letting off the air-pressure periodically to enable the weight of the cylinders, &c., to overcome the external friction, and follow down after the excavation. The day was divided into six shifts of four hours each; the same men working two, or eight hours per day.

RATE of SINKING CYLINDERS at the HIGH-LEVEL PIER-HEAD from May to August 1878.

Material sunk through.	Diameter of Excavation.	Number of days worked.	Distance sunk.	Sunk per day.		Cubic yards.	
				Daywork.	Piecework.	Per foot sunk.	Per day.
	Ft. In.		Ft. In.	Ft.	Ft.		
Clay . .	6 8	11	16 0	1·45	..	1·296	1·88
„	„	8	15 0	1·87	..	„	2·43
„	4 2	3	6 6	2·17	..	0·505	1·09
„	„	4	9 2	2·29	..	„	1·16
Rock . .	5 2	16	9 6	..	0·59	0·778	0.46
„	„	19	13 6	0·71	..	„	0·55
Average in Clay, ordinary day work							1·64
Average in Red Sandstone, working night and day							0·50

The south protecting cylinder has been put down to 53 feet 8 inches below datum, or 20 feet 10 inches into the rock, and the north protecting cylinder 3 feet short of this. The two outer columns, 5 feet in diameter, stop at 29 feet 6 inches, and the two smaller ones at 22 feet 6 inches, below datum. In the cylinders 4 feet in diameter, only one man could work at a time; in the other cases, two men were down at once. From the last column of the above Table, it will be seen that on an average the clay was got out rather more than six times as fast as the rock. A section of the strata met with in sinking the protecting cylinders is shown in Plate 9, Fig. 8. For sinking them, the upper lengths of some of the bridge-pier columns were made use of to continue them up to the staging deck. One slight mishap occurred in connection with this work. On the 28th of August, 1878, the south protecting cylinder, which had stuck fast for about twenty-four hours, although relieved of the counteracting air-pressure, suddenly dropped about 8 inches, on to the bottom of the exca-

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vation, the sides of which had been carefully trimmed round in endeavours to get the cylinder down. The shock consequent on this slip broke the air-lock plate into pieces, which, together with the pig-iron weight on the top, tumbled on to the deck of the staging, breaking some of the 3-inch planks. A delay of about a week was occasioned, while a new air-lock plate was being prepared. The supporting cylinders are filled with Portland cement concrete, composed of 8 parts by measure of shingle and gravel to 1 part of cement. The bottoms of the protecting cylinders are also stopped with the same materials, the first foot in depth being 1 part of shingle to 1 of cement, and the remainder about 3 parts of shingle to 1 part of cement. The air-pressure was kept on for a couple of days, to prevent water working up through the concrete before it had set. For convenience in putting in the connecting piece between the protecting cylinders, as also the hydraulic-lift cylinders and rams, and the covers to the protecting cylinders, a cofferdam, 20 feet by 7 feet 6 inches inside, was formed by driving 6-inch sheeting piles and tipping clay round the outside. The top of this cofferdam was at a level of 1 foot below Old Dock Sill.

The pier girders were put together in the yard in the same relative position as they now occupy, and were riveted in lengths of about 28 feet, for conveyance by rail to the site, where the girders for the bridge piers and platforms were riveted up on the river wall for their whole length of about 80 feet, and their outer ends launched on to the main staging over a trussed platform, and then placed in their respective positions on the caps. When the girders were got on to the caps, and the cross-girders secured in place, the corrugated plates were riveted on them. After the timber roadways on the goods and high-level piers were put down, the Portland cement concrete was laid on the plates. The asphalt was not laid until the buildings were erected, when it was put down in strips of 24 feet by 6 feet, or 144 square feet at one time.

Dredging.

The dredging, to provide a minimum depth of water of 6 feet on the site of the landing-stage, though only 7,000 cubic yards, required considerable time and patience. This was owing to exceptionally rough weather. Work was begun on the 9th of September, 1878, a large centre-ladder dredger having been hired from the Clyde Trustees for the purpose. As the dredged spoil was to be deposited behind the new river wall, two steam cranes

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were erected thereon to discharge the loaded flats. To save the labour of filling skips by hand, the contractor attempted, in the first instance, to fill wagon-bodies on punts directly from the dredger. The punts having been towed up to the cranes, the wagon-bodies were lifted up and placed upon their wheels, and at once tipped. This method, however, was not satisfactory. The wagons, being of only 2 cubic yards capacity, and there being only room for two wagons on each punt, time was wasted; the punts also were far too light for the river. This arrangement, therefore, was soon condemned, and ordinary river flats, dismasted for the purpose, were used for conveying the spoil. Six punts were brought round from Glasgow with the dredger, and when not in use were kept moored alongside the river wall. Six days after their arrival it came on to blow, and the punts were badly knocked about. They were moored two abreast, and lashed end to end with $\frac{5}{8}$-inch chains round two bollards on each punt. Several of these chains snapped, and it was with difficulty the punts were saved from breaking away. One wagon-body was washed off and lost, one punt received so much damage as not to be worth returning to the Clyde, and the remainder were all injured. This, as it turned out afterwards, was not of much importance, as the five punts and the dredger's boats were lost on the way back to the Clyde. On the 15th of September, or three days after the above experience, a punt broke away in the night, and drifting against the goods bridge pier, knocked over two 18-inch columns which were standing in place, being temporarily held in position pending the launching of the girders on to them. Immediately after this the punts were superseded.

During spring-tides no work could be done, as the time when there was neither too much nor too little depth of water for working in was exceedingly short, and whilst the tide ran strongest. Altogether the Clyde dredger was in the Mersey for one hundred and sixty-seven working days, from the 6th of September, 1878, to the 21st of March, 1879. Of this time, owing to rough weather, spring-tides, and a short detention until some of the temporary staging was done with, her engines were running for only three hundred hours, or say thirty days.

Before the dredging round the columns at the high-level pier-head could be proceeded with, it was necessary that the staging-piles should be drawn. Some little difficulty was experienced in this operation. A screw flat belonging to the Local Board was sent down to do the work, which occupied four weeks. On one occasion, having at low water been pinned down to a pile at the

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bow, by two $1\frac{5}{8}$-inch chains, they both snapped without starting the pile.

As the Clyde dredger was not able to take out stuff close round the columns, some other method of finishing off the work had to be adopted. Scraping was the means first attempted, a harrow, made for the purpose, and hauled backwards and forwards by steam winches from two floats, being employed. This was found to make little impression on the clay, and was abandoned after a very short trial. Spoons, worked by hand-winches from barges, were next tried, but proved inadequate for the work. Eventually a dredger belonging to the London and North-Western Railway Company, kept at Garston, a little higher up the river than Seacombe, was obtained. This dredger had a centre ladder, like the one from the Clyde, but placed further forward, so that it was able to work in shallow water, about 10 feet in advance of the hull. With this dredger the work was completed shortly before the landing-stage was ready to be moored in its place. With both dredgers it was necessary, when working in clay, to keep one or two men, with spear-pointed iron bars, constantly watching the buckets as they came up, and loosening their contents when jammed. If this precaution was neglected, the buckets got choked, and work had to be stopped whilst they were cleared out. With proper care, little trouble was experienced from this cause.

Immediately on the stage being placed, a diver was sent down to remove all large boulders from underneath. In three tides the whole site was gone over, and seven stones were brought up.

LANDING-STAGE.—(Plate 9, Figs. 1, 2, 9; and Plate 10, Figs. 10, to 17, 20, 21.)

The landing-stage is 314 feet 6 inches long by 82 feet 1 inch broad for 206 feet of this length, of which 128 feet at the northern end is appropriated to the passenger traffic; and at the southern end there is an embayment 108 feet 6 inches long by 25 feet 8 inches broad for working the goods traffic, which reduces the width over that part to 56 feet 5 inches. It is floated at an average draught of 3 feet 8 inches upon twenty-one pontoons of varying lengths, 10 feet wide by 5 feet 6 inches deep in the frame, placed transversely to the length of the stage; their outer plates are of wrought iron $\frac{1}{4}$ inch thick, stiffened with angle-iron frames 2 feet apart. A flooring 8 inches deep, formed of a plate and reverse angle-iron, is riveted to every frame to stiffen the bottoms of the pontoons. Each pontoon is divided into water-tight compartments about 20 feet long, by whole bulkheads, with an inter-

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mediate half-bulkhead in each compartment. The longitudinal lap-joints are double riveted. The transverse butt-joints, on the sides and bottoms, are single riveted; the joints in the top plating are lapped and single riveted; the rivets are $\frac{5}{8}$-inch in diameter and $2\frac{1}{2}$ inches pitch; those securing the plating to the frames are $\frac{3}{4}$ inch in diameter by 6 inches pitch. Lugs formed of plates bent to a right angle are riveted to the gunwale angle-irons and side-plating upon every pontoon, having a hole in the horizontal flange to take the bolts by which the keelsons are secured to the pontoons. Wrought-iron packing-pieces, upon which the keelsons rest, are riveted to the top plating immediately opposite the lugs. A manhole is provided to each of the compartments. The bottom of every pontoon was cemented over the top of all rivet-heads, and to above the turn of the bilge, with Portland cement and sand in the proportion of 1 part of cement to 2 parts of sand. The remainder of the inside was washed with three coats of strong Portland cement. Four lines of double-web girders, 3 feet wide, form keelsons on the top of the pontoons; three of them extend the entire length of the landing-stage, the fourth finishes with a return girder at the end of the embayment. There are also three intermediate lines of wrought-iron single-web girders with flanges 18 inches wide; two of them extend the entire length of the landing-stage, the third terminates at the embayment. These girders vary in depth from 3 feet 6 inches at the sides of the stage to 4 feet 3 inches at the centre, in order to give a camber of 9 inches to the deck. Provision is made for securing the bridge joint-bed-plates, and for carrying the weight of the bridges at two points in the length of the landing-stage. In these positions wrought-iron girders are riveted to transverse box-girders, which latter are attached to the keelsons.

Upon the tops of the keelsons corrugated plates $\frac{5}{16}$-inch thick, having corrugations 3 inches deep, 12 inches from centre to centre, are riveted breadthwise to the stage. The keelsons are built square on the top, the corrugated plates being packed up by bevelled bars 8 inches wide, on the centre lines of the keelsons, to suit the camber in the deck. The plates are butt-jointed on the centres of the keelsons, and have two corrugations in each plate, with 2 inches lap for riveting, which weigh 33·34 lbs. per lineal foot.

Upon the top of the corrugated flooring plates a deck of greenheart is laid; each plank, 6 inches wide by 3 inches thick, is bolted zigzag as regards the strakes to every fourth corrugation with galvanised bolts $\frac{5}{8}$ inch in diameter. The planks are laid close, and the seams are served with three threads of machine-spun

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oakum and payed. Access to each division between the keelsons is obtained through hatchways in the deck.

Weight of the Deck per square yard.

	lbs.
Corrugated plates (with 5 per cent. added)	157·5
Greenheart planking (taken at 70 lbs. per cubic foot) .	157·5
	315·0

Fenders composed of four pieces of American elm, 12 inches square in cross-section, bolted together, are secured to the posts on the outshore side and ends of the landing-stage, in 18-feet lengths, by bolts 1½ inch in diameter. They are supported at the back by vertical posts of greenheart, also 12 inches square in cross-section, spaced 6 feet apart, bolted at the front of the stage to angle-iron lugs prepared for them on the face of the outermost double-web keelson, and at the ends of the stage to the angle-irons which connect the keelsons together. These fender posts are tenoned into a covering board of greenheart laid round the front and ends of the deck platform. A projection supported upon brackets, formed of wrought-iron plates and angle-irons, is provided midway at the back of the landing-stage to afford access to the hydraulic-lift platforms. Cast-iron bollards for mooring the ferry steamers are fixed along the front and ends of the stage about 12 feet apart. A guard fence, composed of two galvanised short-link chains, supported upon wrought-iron galvanised stanchions, fixed in cast-iron sockets which are let into the deck, extends all round the landing-stage. Life chains, similar to the guard chains, are hung in festoons underneath the face fenders. Bridge rails are laid upon the landing-stage deck, flush with the planking, leading over a single-road turntable 12 feet in diameter, so that wagon traffic can be worked either on to the deck of suitable steamers or alongside of them. The rails over the projection to the lifts are movable, to allow for the up- and down-stream movement of the stage. The travel provided for was 6 inches on each side of the centre position, and since the stage was put in place this has been the maximum travel on very strong tides. The average freeboard of the stage is 6 feet.

GANGWAYS.—(Plate 9, Fig. 2; and Plate 10, Figs. 13, 14, 15 to 17.)

Two gangways for the passenger traffic are attached to the outshore side of the landing-stage, directly opposite the passenger

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bridge, and there are two for goods, fitted for cart and horse traffic, of which one is opposite the goods bridge, and the other at the end of the embayment, so as to form an end-on loading approach to the steamers. These gangways are framed of American oak, bolted together with wrought-iron knees; their attachment is to crossheads of wrought iron, which allow of vertical and lateral movement. They are raised and lowered by chains attached to presses placed horizontally under the deck of the landing-stage, one press for each of the two passenger gangways, with a ram 3 inches in diameter, and two presses for each of the two goods gangways, with rams 4½ inches in diameter, all with 5 feet 6 inches length of stroke. These rams and cylinders are of cast iron; the lifts are controlled by hand and automatic check gear. The levers for working the power are placed conveniently on the deck of the landing-stage.

The two passenger gangways are 13 feet long by 5 feet wide, having a handrail on each side. The end handrail standards are of cast iron, and form the levers through which the power for lifting the gangways is applied; the rest of the handrail is of wrought iron galvanised. The battens for the footways are of greenheart 1 inch thick. Flaps of wrought-iron chequered plate, attached to the stage end of the gangways, cover the joints.

The two goods gangways are each 12 feet long by 7 feet 6 inches wide, having roadway planking of greenheart laid transversely, with a horse track in the centre formed of greenheart battens; angle-irons are bolted at the sides for wheel guards. Two cast-iron columns, fixed upon the deck of the landing-stage at each goods gangway, carry sheaves, over which pass the lifting and lowering chains. These chains are secured to brackets bolted to the sides of the gangways, and work over sheaves on the heads of the rams to allow of lateral adjustment of the gangways. These gangways are also provided with flaps over the joints. The hauling chains for the gangways are all "best best" short-link crane-chain $\frac{9}{16}$ inch in diameter. An arch of cast-iron, in which is cut the name of the ferry, is supported upon columns at each passenger gangway; upon each arch are fixed three shadowless lamps. A steel fog bell weighing 735 lbs. is hung in a stand 7 feet 6 inches above the deck, near the middle of the stage. A fourth order dioptric light, by Messrs. Chance Brothers, with gas burner, is fixed on a cast-iron column 20 feet above the deck alongside the fog bell.

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LANDING-STAGE MOORINGS.—(Plate 9, Figs. 1 to 7.)

The landing-stage is secured in position by 2-inch stud-link cables forming cross-bridle moorings, which are fastened to the cast-iron posts at the back of the river wall; also by fore and aft riding chains attached in the centre line of the stage to single fluke anchors weighing 50 cwt. each, buried in the bed of the river.

The chains pass over cast-iron fairleads bolted on the inshore girder of the landing-stage; they are stoppered with wrought-iron forged stoppers behind heavy cast-iron blocks also bolted to the girder, and tied back with wrought-iron bars. The bare ends of all the chains are led below the deck and shackled to the top flanges of the girders.

In the long cross-bridle chains the amount absorbed by the sag is $1\frac{3}{4}$ per cent. on the horizontal length between the points of attachment, and in the short cross-bridle chains it is 2 per cent.

BRIDGES.—(Plate 9, Figs. 1, 2, 9; and Plate 10, Figs. 10 to 12, and 18 to 25.)

The bridge at the north side, appropriated to passengers, is a double roadway bridge composed of three wrought-iron double web girders of a fish back-and-belly form (both flanges being struck with a radius of 802·86 feet) 165 feet long by 13 feet deep at the centre. The distance between the centres of the joint axles is 160 feet, producing a gradient of 1 in 5 at extreme low water. The middle girder is 3 feet wide, those at the sides are 2 feet, and of proportional sections. Two arched double-web girders connect the main girders overhead, and five single-web girders connect them below the roadways. The roadways, which are fixed half-way up the girders, have each a clear width of 10 feet between the flanges of the girders, and are formed of corrugated plates of the same dimensions as those on the landing-stage, supported by angle-irons riveted to the main girder webs. The webs are well tied together in the line of the roadways. Upon the corrugated plates greenheart planks are laid of the same dimensions and in the same manner as in the deck of the stage. Handrails of teak $2\frac{1}{2}$ inches in diameter, are supported at intervals of 6 feet on each side of the roadways by wrought-iron brackets attached to the webs of the main girders.

A roof covers the double roadway of this bridge. It is formed of arched tee-iron bars 2 feet from centre to centre, and rough

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rolled curved plate glass ¼ inch thick, and supported at intervals of 6 feet upon cast-iron brackets of varying height to suit the curve of the top flange of the girders to which they are bolted. The brackets are connected at the top by angle-irons to which the tee-iron bars are bolted, and also cast-iron gutters; spouts descend at the ends of the bridge. The glass has a lap of 4 inches at the horizontal joints, and is bedded in putty on the bars; it is held in place by cappings of American elm notched to fit over the plates, which are also secured by split pins through the blade of the tee-iron. The glass at the sides is in squares, about 3 feet wide, decreasing in depth towards the middle of the girders, and is fitted into sashes of pitch pine. A moulding of pitch pine is carried on the inside of the gutters, which covers the angle-irons on the tops of the brackets. Three lines of flat bars form longitudinal ties on the tee-iron bars. The rough side of the glass is put on the inside of the roof. The underside of the ridge of the roof is 14 feet above the deck of the bridge. An ornamental fascia of yellow pine, painted, is fixed at the landing-stage end of the bridge and covers the end of the roof.

The south bridge is reserved for the goods traffic; it consists of two wrought-iron girders each of the dimensions and shape of the middle girder of the north bridge, tied together at the top and bottom in the same manner. The roadway, of longitudinal pitch pine 4½ inches by 4 inches, open laid, is supported upon corrugated plates, of the same dimensions as those on the piers, and attached to the webs of the main girders, similarly to those on the north bridge. Greenheart sheathing, laid close and caulked, forms the surface, with a horse and cart track having cast-iron guards at the sides, like that upon the piers. Outside the main girders footwalks are carried upon tee-iron cantilevers, 6 feet apart, riveted to the webs and stiffeners of the girders, upon which pitch pine 9 inches by 4 inches is secured longitudinally, with greenheart sheathing, open laid, for the surface. Three strong guard rails of galvanized wrought-iron steam pipe, are fixed outside of each footwalk, supported at intervals of 5 feet by galvanized wrought-iron forged standards.

Provision is made, in the attachments of the bridges to the piers and landing-stage for the lateral and vertical motion caused by the tide, in the following manner. Cast-iron sockets are securely bolted to the top of the front centre column, and to the transverse box-girders in each bridge-pier, into which are fixed wrought-iron pivots, and upon these wrought-iron crossheads, having bearings at each end, rest and allow lateral motion. The

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pivots on the stage, also carrying crossheads, are fixed in similar cast-iron sockets, bolted to the top of the girders, upon which the bridges rest. Cast-iron saddles are supported by the bearings at the ends of these crossheads and allow vertical motion. The saddles are bolted into heavy wrought-iron cross-girders which are riveted up to the ends of the bridges. Cast-iron plates are bolted to the outer ends of these girders which bear upon similar plates upon the pier-heads, and on the girders on the stage; those under the passenger bridge, on the landing-stage, are of cast steel. All these bearings are machined and accurately fitted.

Flaps of wrought-iron plates with greenheart battens, secured on the top, cover the spaces between the ends of the bridges and the stage and piers.

ERECTION OF LANDING-STAGE AND BRIDGES.—(Plate 10, Figs. 18, 19.)

Six of the pontoons were built close to the edge of the dock in the contractors' yard, and were launched into the dock from ways laid at an inclination of $\frac{5}{8}$ inch to the foot. The remainder were put upon bogies and taken to a crane, where they were lifted into the water with chain slings. When a single pontoon was moved in the water a balk of timber was lashed to each side to prevent it rolling over.

The keelsons were put together in the yard, and the timber was fitted to the front keelsons as they were riveted up, as the timber was more easily handled in the yard under the travelling cranes, than it would have been after the keelsons were in place on the pontoons. The keelsons were riveted in lengths of about 90 feet, taken on bogies, and lifted on to pontoons at the large crane, mentioned above, which is about $\frac{1}{4}$ mile from the yard; they were then floated up the dock to the stage, put in position and riveted up. The corrugated plates were riveted in place, and after the rails had been fastened upon them, the timber was laid from both sides of the stage and from the centre at the same time.

The bridges were built in the contractors' yard adjacent to the West Float for convenience of launching; the bottom end of the goods bridge was flush with the coping line of the dock wall, that of the passenger bridge being 32 feet from that line. They were built upon timber blocks about 4 feet apart, and at the inclination with the horizontal at which it was intended to lay the launch-ways. They were launched, finished complete, except the roof over the passenger bridge, a few of the columns and brackets only for which were bolted in place, upon ways of American oak laid

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under each girder at an inclination of ¼ inch to the foot for the goods bridge, and ⅛ inch to the foot for the passenger bridge. The main girders rested on the ways on pitch pine packings fitted carefully to the round of the bottom flanges, in 12-feet lengths, so that they might fall clear as the bridge was launched out. The ways were supported upon pitch pine blocks, placed 4 feet from centre to centre, built up to the required height, and were shored transversely every 12 feet. The goods bridge, which was launched first, moved easily on its ways as laid, but the passenger bridge required much more power to keep it in motion.

The goods bridge, weighing 240 tons, was launched, and floated to the site of erection, on two "camels" belonging to the Mersey Docks and Harbour Board, 72 feet long, 15 feet 6 inches beam by 9 feet deep in the frame, and two of the pontoons, 80 feet long, from the stage; upon these were placed packings of pitch pine upon which the bridge rested. The passenger bridge, weighing without the roof 252 tons, was carried upon two larger "camels," also belonging to the Mersey Docks and Harbour Board, 72 feet long by 25 feet 6 inches beam, by 10 feet 6 inches deep in the frame. Packings of pitch pine balks were built up on the "camels" and pontoons to a height of 10 feet 6 inches above their decks, so that the inshore ends of the bridges might be sufficiently high above the water to be landed on the axles, on a tide rising only 14 feet above Old Dock Sill, when there would be little current in the river.

The bridges were launched in the following manner. The packings under the main girders having been "set up" with wedges, to ensure the pressure being evenly distributed on the ways, and the "poppet" shores, which had previously held the bridges up while the ways were being put under, having been taken out, the "daggers" at the bottom cleats at each side of the ways were knocked out, and the bridges were hauled down by a tackle, the fall of which was taken round a winch barrel. As soon as a bridge was projected far enough over the dock, the daggers were put in at the next cleats, and a couple of pontoons, with packings upon them, sunk to the necessary depth with water ballast, were brought under the end, and then, by pumping out the water, raised, so as to take part of its weight. Next, one of the two camels which had eventually to carry each bridge, was introduced between the pontoons and the dock wall. The bridge was again projected until the second camel could be placed in position, and afterwards the pontoons were removed, except those between the smaller camels under the goods bridge. As soon as

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they were launched they were taken up the dock, and moored to the stage, to await the necessary height of tide for putting them in place. They were securely shored from the decks of the camels, and the camels were tied together by balks of timber. The camels when carrying the bridges had a freeboard of 2 feet 6 inches.

The tides, which ranged from 14 feet 11 inches above Old Dock Sill on the 20th November, 1879, to 12 feet 8 inches on the 23rd of the month, were considered suitable for putting the landing-stage and bridges in place. These were brought down the Great Float, a distance of about 1 mile, on the morning of the 20th. The bridges were towed by a large paddle tugboat, with a small screw tugboat lashed broadside on astern of the last camel for steering, and the stage was towed in a similar manner. They were all got into the entrance lock of the dock by midday. As soon as the tide allowed, the stage was hauled outside the dock gates, and laid alongside the wall in the river, and the bridges were left in the lock.

At about four hours' ebb the stage was hauled out of the entrance to the dock, and two powerful paddle tugboats were made fast at each end, by which it was towed to its berth. In less than an hour from the time of leaving the dock entrance the stage was got to its site, and the fore and aft mooring-chains, which had been buoyed in position, were then picked up and hauled in; an operation which occupied about two hours more. The anchors were next brought to a bearing by a tugboat, attached to the stage, going ahead and astern.

About two and a half hours before high water on the 21st, the passenger bridge was brought out of dock and dropped into position on the flood tide; just before high water it was secured by moorings until the tide fell, when the inshore end dropped into place on the axle, and released the camel at that end. Owing to the height of the foreshore at that point, the other camel was not got clear until the morning of the 25th.

Next day the goods bridge was brought out of dock, at 8.30 A.M., and got into position an hour afterwards. It was landed on the axles in the same way as the passenger bridge, but without a hitch, and in much less time, both camels and pontoons being clear by 7.30 A.M. on the following morning.

The cross bridle mooring-chains were then picked up, and the lengths of all the moorings adjusted, to bring the stage into position.

The roof over the passenger bridge was erected from a temporary

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staging composed of planks laid upon angle-irons bent to a right angle and bolted to the webs of the side girders. As soon as the tee-iron bars on one half of the roof were bolted in place, the glass was put on and held by temporary zinc clips until the timber cappings were fitted over it.

Weight of Passenger Bridge and Roof.

	T.	cwt.	qrs.
Roof with fascia, &c.	46	10	1
Bridge as launched	251	17	1
Flaps	6	12	2
Total weight in place . . . Tons	305	0	0

FERRY BUILDINGS.—(Plate 9, Figs. 1, 2, 8, 9.)

Under the head of Ferry Buildings are included both the part devoted to passenger traffic and the engine- and boiler-house and accumulator-tower. The former of these, or the station, is erected partly on the quay, but chiefly on the north bridge pier and platform. The portion on the land is built of red brickwork, with sandstone dressings; that on the pier is entirely of timber framing, with the sill bolted down. The framing is filled in with rough "stiling" and side fillets, lathed and plastered on the inside, and externally covered with a sheeting of rebated weather boarding, 1 inch thick. A marginal fascia board, with cusp head, is fixed in each panel. The space from the north side of the high-level pier to the north side of the passenger bridge pier is divided, by two rows of columns, into three bays, each of which is covered by one span of the roof. All wrought timber used in this part of the work is pitch pine, and all exposed to view is varnished. The roof trusses are stop-chamfered, and well bound together with straps and bolts. Longitudinal bearers are laid along the columns, and the roof trusses spring from these and the timber framing of the outer walls. Purlins are attached to the principal backs, supporting 1 inch V-jointed and tongued boarding, laid diagonally. The boarding is covered with Veille Montagne zinc, No. 16 gauge, laid to the Italian roll pattern, an ornamental cresting being fixed along the ridges, with terminals at the ends. Skylights are introduced in the upper portion of each span. Brackets, curved braces, pendants, &c., are fixed in the gables next the river. The office, ladies' waiting-room, and conveniences are partitioned off with timber framing, filled in with rough stiling, lathed and plastered on both sides. In the case of the first-named rooms, the partitions

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are carried up to the roof and glazed. Four toll-houses, in a row, are spaced across the station. Each toll-house commands two turnstiles, room being left at the sides for two more when required. Passengers and luggage pass through both ways in the centre.

The machinery building consists of an engine- and boiler-house in one, and an accumulator-tower; the latter is carried up to a height of 70 feet to the top of the parapet wall, and is utilised as a clock tower. It is covered in with a slated spire or high-pitched roof, having an ornamental finial. There are four illuminated clock dials, 6 feet in diameter. The clock, which is by Joyce, of Whitchurch, gives one stroke on a 2-cwt. bronze bell every quarter of an hour, for starting the boats. The firing platform for the boilers is outside the building, and is covered by a lean-to roof. The walls of the machinery building are of brickwork, similar to that in the passenger station, and the roof is covered with Welsh duchess slates, rendered underneath with hair mortar. The foundation for the tower is brought up from the "growing clay" of the old foreshore in a solid mass of concrete. The engines are fixed with Lewis bolts to Runcorn ashlar, set on a bed of Portland cement concrete; the total depth of ashlar and concrete is 5 feet 3 inches.

The land front of the passenger station is provided with a covered way, constructed of ornamental cast and wrought iron-work; the roof is in three spans, glazed with rough plate-glass.

Capstans.—(Plate 9, Fig. 2.)

Three of Brotherhood's patent three-cylinder hydraulic capstans are placed upon the works, one on the landing-stage, for working wagons along the rails on the stage, and on and off the lift platforms; another on the high-level pier for working wagons along the pier, and on and off the lift platforms; and the third on the pier at the top of the goods bridge, for helping carts up the bridge when the inclination is too great for the horses to draw up the loads unassisted. The cylinders of the capstans are $5\frac{1}{4}$ inches in diameter by 4 inches length of stroke. The capstan on the high-level pier is over the centre longitudinal girder, to obviate cutting which the engine is placed in a cast-iron casing on the top, and it is raised by two rams 3 inches in diameter by 18 inches stroke, one ram on each side of the flange of the girder, when it requires packing, &c. The capstans are each capable of a minimum pull of 20 cwt. on the level, with a pressure of 600 lbs. per square inch.

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Pressure and Return Pipes.

The pipes for conveying the pressure to the lifts, capstans, and gangway presses, and for returning the water in summer or anti-freezing mixture (which is composed of about 3 parts of water to 1 of crude brown glycerine) in winter, to the tank over the pumps in the engine-house to be again used, are 4 inches and 5 inches in internal diameter respectively at the pumps, decreasing to $\frac{3}{4}$ inch and 1 inch in diameter at the gangway-presses and capstans, of cast iron, on the piers carried by wrought-iron hangers under the deck, and of wrought-iron 2 inches in diameter down the goods bridge and on the landing-stage, with joints of gun-metal, to allow of the motion of the bridge at each end. The pipes from the lift-valves on the high-level pier to the lift cylinders are of copper $1\frac{1}{2}$ inch in internal diameter.

Accumulator.

The accumulator-cylinder and ram are of cast iron, 18 inches in diameter by 20 feet length of stroke, with a weight case 9 feet 9 inches in diameter, by 21 feet deep, of wrought-iron plate $\frac{1}{4}$ inch thick, attached to the ram head by a crosshead, also of wrought iron, and ballasted with slag, to give a pressure equal to 600 lbs. on each square inch of the ram. When the attendant leaves in the evening, the accumulator weight-case is left at the top of its stroke, to work the passenger gangways for the boats, which run hourly during the night.

Engines and Pumps.

The pumping power is derived from a pair of direct-acting horizontal high-pressure engines capable of being worked both in gear and by hand either jointly or independently. Each engine has the force pump between the cylinder and crank, the connecting-rod being forked to permit of this arrangement, and the pump-ram is attached to the motion-block; the engines are coupled by cranks set at a right angle. The steam-cylinders are 15 inches diameter by 24 inches length of stroke; the pumps are double-acting, with plungers 6 inches in diameter. The engines are automatically controlled by the accumulator, in addition to the ordinary screw-down valve. The pumps are supplied from the return water-tank, which is in close proximity, with a head of 18 feet.

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Boilers.

The boilers are in duplicate, of the Cornish type, 22 feet long by 6 feet in diameter, with a flue 2 feet 9 inches in diameter, fitted with six Galloway tubes, and are set with an inclination to the front of 1½ inch in their length. Instead of steam domes, they have a perforated steam collecting pipe, 6 feet long by 4 inches in internal diameter. They are fed from a wrought-iron cistern above them, into which the township water is laid, either by an injector or a pump worked from the crank of one of the engines, and are arranged so as to be capable of being worked either together or separately, and of supplying the engines with steam at a working pressure of 80 lbs. to the square inch.

Gas Service.

The top handrail on the piers forms the gas service to the lamps; the pipes to the stage are led down inside one of the girders in each bridge, having brass universal joints at the ends. The north bridge is lighted by shadowless spherical lamps, one under each of the overhead ties in the roadways, and the south bridge by square lamps fixed on the top of the overhead arches. The stage is lighted by square lamps upon standards, and the gangways by three spherical lamps upon each arch. All the ferry buildings are lighted with gas; the passenger station having eight Argand lamps suspended from the roof, and ordinary brackets and pendants being fixed in other places where needed.

Painting.

The castings for the columns, &c., were coated with black varnish before leaving the contractor's yard; those for the handrail standards and entablature were covered with boiled oil, as they were afterwards to be painted. The whole of the wrought-iron plates and bars used in the work, except those for the pontoons, were covered with boiled linseed-oil before they were incorporated in the girders, &c.; the girder-work, upon being riveted up, received two coats of oil paint in the yard. As soon as the pontoons were riveted up, caulked, and tested, they were covered outside with one coat of boiled linseed-oil, and, after the oil was dry, with two coats of red lead in oil, and a finishing one of black varnish. The top of the corrugated plates, on the outer portion of the high-level pier and on the landing-stage, was covered before the timber was laid with a mixture of pitch and tar of such consistency that it did not run

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off or crack when dry; the underside is painted the same as the girders upon which the plates rest. After erection, the cast-iron columns in the piers received two coats of black varnish, and the girders, up to the roadway line, one coat. The keelsons, when riveted up on the pontoons, had a finishing coat of red lead in oil. The bridge girders received a finishing coat of chocolate colour; the passenger bridge roof outside is zinc colour, and shades of blue inside. The engines are painted a light chocolate colour, with the flanges picked out in black. The outside of the timber framing of the passenger station is stopped-in, primed, and painted with four coats in oil and white lead, the main timbers being finished a dark olive green, the panels chocolate, and the marginal fascias, &c., a light stone colour. The inside is stained and varnished with two coats of copal.

Approach Road.—(Plate 9, Fig. 1.)

The new approach road is 122 feet wide, and on a gradient of 1 in 47. The foot-walks are laid with Yorkshire flags and granite curbs, that on the north side being 18 feet, and on the south 12 feet wide, leaving a width of carriage-way of 92 feet. Along the south side of the road a tramway, on Barker's system, has been laid by the Wallasey Tramways Company, their engineer being Mr. Charles H. Beloe, M. Inst. C.E. The whole of the carriage-way between the channel stones, except crossings, and along the tramway, which was paved by the company, is formed of Penmaenmawr macadam and Portland cement concrete, sufficient chippings and gravel being used to fill up the interstices. The proportion was 8 parts of aggregate to 1 part of cement, and the thickness of the metalling was 9 inches. No pitching or hard core was used, the concrete being laid directly on the clay, which was first rolled till brought to a good even and solid surface. The road in front of the goods department is paved with setts from the old slip. The gas and water pipes and the surface drain pipes for that side of the road are brought down in a subway under the north footwalk. The lighting is effected by single lamps along the sides, and two large lamps, one with five lights and the other with three, in the middle, at top and bottom. Along the south side of the road is a brick retaining wall with a hoarding on the top.

Railway.—(Plate 9, Fig. 1.)

In order to preserve a frontage to the new road in the plot of reclaimed land bordering its south side, and in view of the fact

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that until accommodation is provided on the Liverpool side no cross-river traffic can be conducted in loaded railway wagons, the Board determined that the reclaimed land should be skirted by a railway, with the intervention of two turntables, curving round to form a junction with the dock rails. The road is a double line, laid with double-headed iron metals, weighing 60 lbs. per yard. It is intended that this ground shall be also used as a railway depot, and a portion of it is paved with this object. A weigh-bridge with sunk rails, suitable for either carts or railway wagons, is fixed on the down line.

Tests of Materials, &c.

From each consignment of Portland cement delivered on the works samples were taken and tested in the customary manner. The results showed a tensile strength varying from a minimum of 528 lbs. per 2¼ square inches to a maximum of 1,040 lbs., the average being 737 lbs. The tests were made seven days after gauging, the test bricks having been kept for the last six days under water. The residue of the cement, when passed through a 50-gauge sieve, ranged between 13¾ and 28 per cent.

The cast iron in the works stood the following tests:—Bars, 5 feet long by 1 inch square, were cast at the same time as some of the cylinders, &c.; these were placed on bearings 4 feet 6 inches apart, and a load was suspended from the centre; the average breaking weight of twelve bars was 612 lbs.

Test bars were cut from each delivery of wrought-iron plates, angle- and tee-irons, and tested at the Mersey Docks and Harbour Board's hydraulic machine at Birkenhead, with the following average results:—

Materials.	No. of Tests.	Breaking strain per square inch.	Elongation in 12¼ inches.
		Tons.	Per cent.
Tee-iron	3	23·1334	9·08
Angle-iron	16	22·3371	8·76
Plates	20	21·9943	6·72

The specified breaking strain was 21 tons per square inch.

After the pontoons had been riveted up and caulked, but before any painting outside or cementing inside was done, every compartment in each pontoon was separately filled with water, and proved perfectly tight.

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The mooring chains were proved at a public machine to 10 per cent. over Admiralty proof strain for chains of their diameter. A piece, six links long, cut from each of the eleven lengths, was broken with an average strain of 114·14 tons. It was specified that the breaking strain should not be less than 50 per cent. over Admiralty proof strain, or 108 tons. The anchors were also tested at the same time.

The lift cylinders and rams were tested, and proved sound castings by hydraulic pressure; the former with a pressure of 2,240 lbs. per square inch, the latter with 1,000 lbs. to the square inch internally. The accumulator cylinder was tested with the ram inside with a pressure of 2,240 lbs. per square inch. The gangway presses, pipes, and other parts subjected to hydraulic pressure were tested with a water-pressure of 2,250 lbs. per square inch.

The boilers were tested and proved tight, with a hydraulic pressure of 140 lbs. per square inch.

Prices, and Cost of Works.

The sectional area of the 24-feet wall is 43⅜ square yards, and the cost per lineal yard was £63 2*d.*, or with counterforts, £65 10*s.* 5*d.* For the 27-feet portion, the figures are: sectional area 47½ square yards, and per lineal yard, £69 8*d.* and £72 3*s.* 4*d.*; the latter not including the bridge pier abutments and steps. The weights per square foot on the foundation, including the counterforts, are (allowing 17 cubic feet to the ton) 1·455 and 1·577 ton respectively.

The following were the principal rates paid for the river wall and earthwork:—

	£	s.	d.	
Excavating any kind of material from the foundation trench, and running to spoil within 20 yards	0	8	0	per cubic yard.
Excavating bowling green, &c., and depositing material on reclaimed land	0	1	4	„
Supplying and depositing filling	0	2	4	„
Rock rubbish for backing up the wall	0	3	6	„
Concrete laid in any position at any part of the works	1	3	0	„
Soft stone masonry in the river wall, including coping	1	9	4½	„

Note.—The style of masonry having been modified by agreement from that specified, this price was arrived at as an average of the rates in the original contract.

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	£.	s.	d.	
Brickwork in bridge pier abutments	1	14	6	per cubic yard.
Granite ashlar under cast-iron bed-plates for pier girders	0	5	9	per cubic foot.
Granite steps	0	7	5	„
The price charged to the contractor by the Dock Board, for mortar loaded into his wagons at the mill was	0	12	0	per cubic yard.
The price allowed by the contractor for old masonry, measured in place before being touched, and used in the new work, was	0	5	6	„

The following are some of the principal rates for the iron and timber work, erected complete in place, in the piers and landing-stage :—

	£.	s.	d.	
Columns 5 feet and 2 feet 6 inches in diameter.	18	0	0	per ton.
Columns 18 inches in diameter	16	10	0	„
Protecting cylinders 5 feet in diameter, in clay	19	0	0	„
Girders in piers	17	0	0	„
Pontoons	18	10	0	„
Keelsons	17	10	0	„
Main girders, goods bridge	19	10	0	„
Centre girder, passenger bridge	19	10	0	„
Outside girders, passenger bridge	19	0	0	„
Arched stays to bridge girders	21	0	0	„
Bottom stays to bridge girders	18	0	0	„
Box girders for bridge joints	18	0	0	„
Corrugated plates on piers, stage and bridges	17	10	0	„
Mooring chains, 2-inch stud link	21	0	0	„
Portland cement concrete in columns and on piers and platforms	1	0	0	per cubic yard.
Asphalt on piers and platforms	0	10	0	per square yard.
Greenheart planking on piers including caulking and fastenings	0	14	0	per cubic foot.
Greenheart planking on stage and bridges, including caulking only	0	14	0	„
Greenheart battens in horse track, and on footways, without fastenings	0	13	0	„
Pitch pine on goods bridge, without fastenings	0	5	0	„
American elm face fenders, without fastenings	0	7	0	„

Cost of a square yard of Landing-Stage Deck only.

	£.	s.	d.	
157½ lbs. corrugated plates at 17s. 6d. per cwt. =	1	4	7¼	per square yard.
2¼ c. ft. greenheart planking at 14s. per c. ft. =	1	11	6	
	£2	16	1¼	

Cost of Landing-Stage per square yard of deck area.

	Ft.	In.		F.	In.	
North end of stage	202	0	× 80	0	=	1,795
South end of stage	108	6	× 54	4	=	655
						2,450 square yards of deck area.

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	£	s.	d.	£	s.	d.	
Pontoons	8,011	19	9 =	3	5	4·84	per sq. yd.
Keelsons	7,402	11	1 =	3	0	5·14	„
Deck, face fenders, lamps, &c.	8,949	15	10 =	3	13	0·71	„
Total cost of landing stage	£24,364	6	8 =	9	18	10·69	„

Principal rates paid for approach road and railway:—

	£	s.	d.	
Brickwork in retaining wall along new road	1	0	0	per cubic yard.
Brickwork in walls of subway	1	6	0	„
Penmaenmawr stone and Portland cement concrete in carriage way, 9 inches thick	0	5	0	per square yard.
Yorkshire flags in footwalks	0	5	6	„
Rock pitching and boulder paving to railway	0	4	6	„
Railway (60 lbs. iron metals) laid complete, all points and crossings included (single track)	1	1	0	per lineal yard.
13-feet turntables	105	0	0	each.
Weighbridge and office complete	205	13	6	

Cost of Works.

	£	s.	d.	£	s.	d.
Foreshore purchased from H.M. Commissioners of Woods and Forests	2,980	0	0			
Charges in connection with conveyance thereof	85	14	6			
				3,065	14	6
Temporary ferry:—						
Landing-stage, bridge, and timber pier	3,893	16	0			
Rent of premises for approach	1,022	19	7			
Removing landing-stage, and bridge	155	6	5			
				5,072	2	0
River wall and reclamation:—						
Borings	47	5	0			
Masonry, &c., in river wall	22,930	12	8			
Masonry in bridge pier abutments	1,734	9	10			
Masonry in mooring chambers	601	9	10			
Shore attachments for landing-stage moorings	81	10	2			
Mooring posts on river wall	43	8	2			
Earthwork	14,040	13	0			
				39,479	8	8
Dredging				6,337	12	0
Bridge piers				10,470	15	0
High-level pier				11,449	16	6
Platforms between piers				3,793	11	5
Landing-stage				24,364	6	8
Landing-stage moorings				1,514	18	11
Passenger bridge and roof:—						
Bridge	5,228	14	8			
Roof	1,553	8	1			
				6,782	2	9
Goods bridge				4,450	10	7
Carried forward				116,780	19	0

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	£.	s.	d.	£.	s.	d.
Brought forward . .				116,780	19	0
Hydraulic machinery:—						
Two Cornish boilers	617	4	9			
Two engines and pumps	907	4	5			
One accumulator	496	0	0			
Three capstans	522	9	0			
Two lift-platforms with movable roadways, cylinders, and rams	1,736	12	7			
Two passenger gangways with presses, &c.	226	18	6			
Two goods gangways with presses, &c. .	513	4	1			
Pressure and return pipes for entire system	856	3	3			
				5,375	16	7
Ferry buildings:—						
Passenger station	5,008	6	0			
Machinery shed	2,503	1	3			
				7,511	7	3
Approach road				3,137	8	7
Railway				1,772	4	4
Engineering:—						
Commission, salaries, and wages . . .	3,329	2	0			
Stationery, and printing reports . . .	75	17	4			
Instruments and models	75	16	6			
Advertising for tenders	123	17	11			
Rent of temporary offices	28	11	7			
				3,633	5	4
Miscellaneous:—						
Interest on loans	4,083	3	5			
Use of dock line of railway, &c. . . .	261	8	9			
Lamp sheds on piers	261	1	6			
Stagemen's huts, &c., on landing-stage .	149	13	7			
Glycerine for hydraulic pipe system .	102	17	1			
Law expenses	147	5	6			
Incidental and other expenses . . .	291	18	1			
				5,297	7	11
Total cost of works				£143,508	9	0

The whole of the works described, with the exception of the ferry buildings, which were entrusted to Mr. G. E. Grayson, architect, of Liverpool, and carried out by him under the supervision of Mr. E. W. Nobbs, are from the designs, and have been constructed under the supervision of Mr. William Carson, M. Inst. C.E.; the Authors, Messrs. Wilfrid S. Boult and John J. Potts, Assoc. MM. Inst. C.E., were the resident engineers; the former having charge of the reclamation, foundations of piers, dredging, and road and railway construction; and the latter of the superstructure of the piers, landing-stage, bridges, and machinery.

The contractors were as under:—For the river wall and earthwork, Mr. Thomas Monk, Bootle; Mr. E. S. Cornish acting as his

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engineer. For the piers, landing-stage, and bridges, Messrs. Thomas Brassey and Company, Canada Works, Birkenhead, Mr. J. W. Woodford at first being in charge. On the death of this gentleman, Mr. James Rodgerson, Messrs. Brassey's manager, took upon himself the personal superintendence of the work. For the hydraulic machinery and all in connection therewith, Messrs. the Hydraulic Engineering Company, Chester, under the direction of Mr. E. B. Ellington. For the dredging, Mr. George Lawson, Glasgow. For the ferry buildings, Messrs. Holme and Nicol, Liverpool; and for the approach road and railway, Mr. Isaac Anwell, Liverpool.

Opening of the Works.

At noon, on the 5th of January, 1880, the passenger boats began to ply from the new ferry; and from the 1st of April following the goods traffic has also been conducted at the new stage, the luggage boat running at intervals of two hours up to the 1st of June, and since this date every hour. On Good Friday, the 26th of March, 1880, the Seacombe boats conveyed 14,133 passengers across the river; and on Whit Monday, the 17th of May, 1880, 22,969 passengers. As some of the horses in carts using the lifts showed signs of timidity at the sight of the water, door screens have been fixed at the ends of the platform roadways.

The floating stage and bridge forming the temporary landing were removed on the 23rd of July, 1880. The former was towed higher up the river and beached above high-water mark, the bridge was removed on a river flat and a "camel" to the top of the great float, where it was placed on land belonging to the parish. The timber forming the approach to the shore end of the bridge was then cleared away.

The Paper is accompanied by copies of accepted tenders for several of the contracts, and by numerous drawings, from which Plates 9 and 10 have been engraved.

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(Paper No. 1872.)

"On the Independent Testing of Steam Engines and the Measurement of Heat used."

By JOHN GEORGE MAIR, M. Inst. C.E.

THE Author of this Paper does not propose to bring before the Institution any new system for the measurement of heat-units used by steam engines, or any new theories connected with the various exchanges of heat during the passage of the steam from the boiler, through the cylinder, to the condenser; but only to point out how the testing of engines, and the measurement of the heat used ought to be carried out, and to give some examples from his own practice. He trusts that in future all engines may be tested independently of their boilers, and that the heat-unit may be adopted as the unit of measurement, instead of the present system, which, in giving the number of lbs. of coal per HP. per hour, mixes up, in the most unintelligible manner, the engine, the boiler, the quality of the coal, and the way in which it is used.

As long ago as 1839, Mr. Parkes, one of the earliest writers on the Cornish engine, expressed very strong opinions against using lbs. of coal as a unit of measurement,[1] stating that the effect of such a system "mystifies the subject, tends to obscure our knowledge of the actual degree of excellence attained by the steam engine, and retards the extension of the most effective system of applying steam; the generation and the application of steam being distinct problems, require to be treated separately."

In these days of universal competition, a reduction in the quantity of fuel burnt is of primary importance, and it behoves all engineers and users of steam power to understand not only the general principles which govern the use of steam in engines, but also to be able to test such engines and boilers as may be under their control. Engineers and manufacturers ought also to unite in their endeavours, the one to turn out the best machinery that can be made, and the other to specify only that type of engine which is the most economical and suitable for the work to be done.

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[1] Transactions Inst. C.E., vol. iii., p. 49, and Minutes of Proceedings Inst. C.E., vol. i. (1839), p. 54.

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If engines and boilers were to be always independently tested many faults in both would be ascertained, which, when rectified, would result in a great saving of fuel, and consequently money. Not only that, but those in charge of the engine would be able to ascertain exactly what the duty of the engine was, and, as a consequence, many of the present extravagant types would soon fall into disuse, and a higher class of engine in every respect be generally adopted. The evaporation of the boiler would be known, and the relative values of different kinds of fuel ascertained. Boiler insurance companies have done much good in testing engines,[1] and directing attention to their faults; but by far the larger number of engines and boilers, whether used for manufacturing, pumping, or other purposes, are either entirely neglected or handed over to the charge of persons ignorant of their duties, and, as a consequence, are most extravagant in fuel.

By the present mode of testing, good engines are often reported as extravagant and wasteful, from being supplied with steam from boilers of a bad design; and many boilers are condemned through being badly stoked, or on account of the engines supplied by them using so much steam. Again, steam is often taken from boilers for heating or other purposes, in addition to the engine supply, so that, unless means of independent testing be carried out, it is an impossibility to divide and proportion the consumption of water and fuel between engine and boiler.

In testing, the general principle to be adopted is as follows:— The power, by means of the indicator, is to be obtained, and at the same time the feed-water measured, its temperature and the boiler pressure taken, and the weight of fuel burnt ascertained. This practically gives the necessary data for calculating the quantity of heat used per HP., and, in addition, the evaporative efficiency of the boiler per lb. of fuel burnt.

Of course many other observations must be taken into account as well, but these measurements embody the general principles for ascertaining the efficiency of the engine and boiler. Where possible, the heat rejected is to be ascertained, as a check on the feed used, and therefore on the heat supplied by the boiler, as the heat used by an engine is equal to the work done, expressed in thermal units, together with the heat rejected.

The rejected heat found in the air-pump discharge must be divided into two distinct parts, one part being the heat retained

[1] Annual reports of the various companies, and especially those of the Engine, Boiler, and Employers Liability Insurance Company for 1880 and 1881.

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in the condensed steam which flows away with the discharge, and the other the heat absorbed by the injection water. The first is found by multiplying the weight of steam passing through the cylinder by the heat-units, due to the temperature of the air-pump discharge. The second is found by multiplying the lbs. weight of the injection water by the difference of the heat-units, due to the rise of temperature in the condenser. As the specific heat of water does not vary appreciably between these temperatures, the difference in the temperatures may be used as a multiplier in place of the difference of heat-units. The correct measurement of injection water used by engines is not so easy to obtain as the air-pump discharge, consequently this latter is the quantity generally measured, and by deducting from it the weight of water passing through the cylinder the weight of the injection is found. Where the boilers supply steam for more engines than the one under test, or for other purposes, and such supplies cannot be shut off, the measurement of the heat rejected is the only means of testing; and to ascertain the thermal units used by an engine so tested the work must be added to the rejected heat. Messrs. Bryan Donkin and Company, on the various trials they have made on this system, have adopted as a unit of measurement "Pound-degrees per horse power,"[1] obtained by multiplying the total air-pump discharge by the difference in temperature between the injection water and the hot well, and dividing by the indicated work. It is undoubtedly a very valuable one for determining the relative efficiency of an engine under different conditions and at various times, but it is not perfectly correct to base on it the relative efficiencies of different engines, as it does not take into account the heat given up by the jackets; and even if it did, the number of thermal units used by an engine cannot readily be obtained from it, unless the water fed into the boilers has the same temperature as the injection water.

In the various trials made by the Author, all measurements and observations have been taken that were possible, and of value; and from the data obtained the thermal units used by the engines per HP. calculated, which gives the only perfect comparison that can be made of the efficiency of engines. To compare the lbs. of water or steam used is only absolutely correct when the steam-pressures are the same, as the total heat of steam varies with the pressure; but, as such variations are very small between the

[1] Minutes of Proceedings Inst. C.E., vol. lxvi., p. 278. "Engineering," July 17, 1868; May 21, 1869; Nov. 3, 1871; Nov. 29, 1872; Feb. 1, 8, 15, 1878.

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ordinary ranges of pressure, the lbs. of dry steam may be taken as a unit of measurement without appreciable error, and this method is used by some writers on the subject, although thermal units are preferable.

The practical measurement of the heat-units used by engines was first carried out, the Author believes, by Mr. Hirn, about 1854, and has been much adopted in France, Belgium, and Germany. Mr. Hirn, Mr. Hallauer, and others, have not only tested engines on this system, but have analysed and investigated the relations that exist between the various exchanges of heat that take place during the stroke, namely, the abstraction of heat from the steam on admission, resulting in initial condensation, and the absorption of heat by the steam during expansion and exhaust. Short accounts of their trials have appeared from time to time in the Foreign Abstracts in the Minutes of Proceedings.[1]

Messrs. B. W. Farey and Bryan Donkin, jun., were the first to take up this independent method of testing in England; but up to this time it has not been much used, nor has it met with the approval it deserves. It is, however, such an excellent system, that, in course of time, it will undoubtedly be generally adopted. Professors Rankine and Cotterill, and others in England, have given much attention to the theory of the steam engine; and, when practical trials have been more largely made, it is to be hoped that science will enable engineers to produce engines of a greater efficiency than any at present in use. By this system of testing, the relative values of compound or simple engines can be settled, and the saving by the use of steam jackets absolutely proved.

The Author will first give a general statement of the manner in which his trials have been made, and then give the necessary formulæ and calculations for one trial, and conclude with a few remarks based on the results obtained.

Measurement of Power and Work.

To test engines of large power on a friction brake is a very difficult undertaking, and the few experiments that have been made[2] all show that, in the same engine, the frictional losses remain nearly constant for all grades of expansion; the efficiency of an engine therefore decreases as the rate of expansion is increased, or,

[1] Vols. xliv., p. 293; xlvii, p. 376.

[2] Minutes of Proceedings Inst. C.E., vol. lxii., p. 386.

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in other words, the percentage of loss is least when the power developed is the greatest. This law holds good for both compound and single-cylinder engines; but as the loss depends so much upon the quality of workmanship, friction of pistons and journals, and on so many other points, no accurate comparison can be made between various types. The results of the brake trials carried out at Cardiff in 1872, with portable engines,[1] reported upon by Messrs. F. J. Bramwell and W. Menelaus, indicating from about 10 to 25 HP., bears out this fact, as the percentage of loss ranged from 8 per cent. to 21 per cent., and in one case was as great as 34 per cent. The Author has found that the losses with large beam compound pumping engines range from about 18 to 20 per cent. for high lifts of, say, 130 feet and upwards, but for lower lifts they are greater, the average of four experiments with a 35-feet lift giving 27 per cent. These percentages include the friction and loss in the pumps as well as in the engines, and are obtained from the actual measurement of the water pumped. On the trials made by the Author the indicated and total powers only are given, and from them the thermal units used by the engines are calculated. To obtain a correct mean value for the power given out indicator diagrams require taking very frequently, and on the trials they were taken every fifteen or twenty minutes, according to the regularity of running, which, in the case of the pumping engines, was naturally very uniform. All the diagrams have had the areas ascertained by planimeters, and mean diagrams made, the point of cut-off, and the pressures of admission and exhaust, being carefully measured and averaged. The pressure at the moment of exhaust is of so much value in analysing the action of the steam during the stroke, that it would be of great advantage if, as suggested by Professor Cotterill, a special instrument could be devised for the purpose of registering it.[2] The indicators used were tested, both for pressure and vacuum, after every trial, by connecting them with a mercurial column, and corrections where necessary have been applied in making the mean diagrams. The springs were as weak as could conveniently be used, so as to get as open a range as possible,[3] and thereby obtain reliable results. The

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[1] The Journal of the Royal Agricultural Society, vol. ix., second series, 1873, p. 51. Also Minutes of Proceedings Inst. C.E., vol. lii., p. 151.

[2] "The Steam Engine considered as a heat engine." By James H. Cotterill M.A., 1878, sec. 127.

[3] Modification apportée à l'Indicateur de Watt, par G. A. Hirn, note presentée à la Société Industrielle de Mulhouse, le 29 Sept., 1875.

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indicator pipes on the engine were arranged to be as short and direct as possible, an important point where great accuracy is desired. With the beam engines the motion for the indicator barrels was taken from the radius-rod, the error in using this motion being so small as to be of no consequence. Reductors, with the cord fixed to the piston-rod crosshead, give the most direct and the truest motion, but there is trouble with them, owing to the springs breaking, and their otherwise getting out of order.

On referring to the Tables accompanying this Paper, the work, as shown by the diagrams, will be found divided as follows: The high pressure into absolute work of full admission, absolute work of expansion, work of compression, and work of expulsion; the low pressure into indicated work, work of expulsion, and of compression. These are expressed in thermal units, and if required to be reduced to foot-lbs., must be multiplied by 772. This value has been used throughout the calculations, as nearly all the Tables of the properties of steam are based on it, although the most recent experiments of Dr. Joule, published in the Reports of the British Association, give a slightly higher value for the mechanical equivalent of a thermal unit.[1] The total HP. or work is the indicated power, plus the work of back-pressure as measured to the line of pressure corresponding to the temperature of the condenser, the absolute HP. or work being that measured to the line of perfect vacuum, as taken from the height of the barometer during the trial. The loss from back-pressure varies with different engines, and in the tables will be found the percentages due to it.[2] The number of strokes was in all cases registered by counters, and the boiler pressure from the reading of solid mercury column pressure-gauges, or from Bourdon gauges previously tested against a mercury column. On some of the trials the temperature of the steam was ascertained by thermometers, but as the readings were always found to agree practically with that due to the pressure, the observations have not been given in the Tables.

Measurement of Feed-Water and Jacket Drains.

The quantity of feed-water used by an engine is one of the most important data in engine-testing, and special care ought to be

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[1] Reports of the British Association for the Advancement of Science, 1873, 1876, 1878, 1879. Also Minutes of Proceedings Inst. C.E., vol. lxix., p. 295.

[2] Note sur les variations du vide on contrepression dans les cylindres des machines à vapeur, par M. O. Hallauer, 1874.

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taken in the measurement of it. The arrangements adopted on the trials were very simple, as will be seen from Plate 11.

The feed was delivered into the upper or measuring tank A, which was set level from a line drawn round it, and to ensure it being filled every time with exactly the same quantity of water, an overflow, or dribble-pipe B, was fixed in it. The exact weight of water this tank contained at a known temperature, when filled up to the overflow, was ascertained by weighing it several times on a tested machine, the greatest difference in the experiments never exceeding $\frac{1}{4}$ per cent.

The method of feeding the boilers on the trials was as follows: When the water stopped running out of the overflow pipe B, the cock C was opened, allowing the water to pass into the large bottom tank D, from which it was pumped into the boiler by a donkey-pump or injector. The assistants in charge of the feed quickly found out the rate the water required to be pumped into the boilers, and arranged the supply so as to keep up a continuous feed. The number of tanks used was taken by two observers, one of whom filled the upper tank and took the temperature of the water, and the other regulated the donkey and feed, their figures being compared every hour during the trials. The level of the water in the boilers was kept as low as possible, to increase steam room and prevent priming, and was left at the end of each trial the same height in the gauge glasses as at the commencement. All pipes and cocks in connection with the boilers were examined, and any leakage made good, before the trials were begun. The water condensed in the jackets was caught in buckets, the cocks and traps being wide open, care being taken not to allow live steam to blow through. The buckets were filled up to a fixed height every time, and for each trial several buckets were accurately weighed and the average taken. The assistant in charge of the drains noted the time at which each bucket was filled, and whether from high pressure, low pressure, or receiver, all the drains being kept separate, except on the series of trials D, E, F, with the Woolf beam mill engine. The separate weights given in the Tables for these have been proportioned from the other trials.

Measurement of Air-pump Discharge.

The arrangement adopted for measuring the air-pump discharge will also be seen from Plate 11. The discharge was led from the hot well by a pipe to a tank D, fitted with baffle-plates, and having a circular slot-gauge E at the end, the head of water over the

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centre of the slot being taken every ten minutes throughout each trial from the reading of a large water-gauge F, and was kept at a height of about 1·8 foot to 2 feet. Eighty-one experiments were made to ascertain the exact discharge through the gauges, the average coefficient being 0·618; it was practically the same for each diameter of gauge tested. The coefficients were very uniform, and the experiments were made when the gauges were fixed in the measuring tank itself, and under almost the same conditions as on the trials. The advantage of this mode of measurement over the tumbling bay or weir used by Messrs. Farey and Donkin, is that any slight error of observation in reading the head over the slot, has not so much influence on the calculated quantity of water discharged as a similar error would have in the head over a tumbling bay. This arrangement of tank and slot-gauge is an easy one to fix, and it would be well if it were attached to all condensing engines, so that at any time the discharge could be measured, which, when multiplied by the difference in temperature between the injection water and the hot well, would give, as explained before, a figure of great value for the engine under test, when compared with the power exerted. On two of the engines tested surface condensers were used, and in those cases the measurement of the air-pump discharge could not with accuracy be carried out. The temperatures of the injection water and the hot well were taken by mercurial thermometers of very open range, made by Messrs. Pastorelli and Rapkin, of Hatton Garden, and verified at Kew Observatory before, and re-checked after, the trials.[1]

Priming Water.

Two systems have been proposed by Mr. Hirn for ascertaining the amount of priming water contained in steam.[2] One, which is really dependent upon the measurement of the total heat of steam, is to condense, in a known weight of water, a certain weight of steam, and by noting the rise in temperature of the water, the increase in weight, and at the same time accurately taking the steam pressure, the amount of water mixed with the steam can be determined. The other is to compare the rejected heat with the heat passing through the engine; but as it is not possible to

[1] On the trials made in Alsace air thermometers were used, *vide* "Note sur le thermomètre différential à air, par H. O. Hallauer," 1874. Messrs. Donkin have applied a registering thermometer to obtain the mean temperature of the air-pump discharge. "Engineering," July 17th, 1868.

[2] Bulletin de la Société industrielle de Mulhouse, 1869, p. 543.

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correctly estimate all the losses, and to take all measurements sufficiently accurate for making such a delicate experiment, this method cannot be carried conveniently into practice.[1] The Author has made many experiments on the first of these systems, but the results have not been so satisfactory as could have been desired. Mr. Hirn and others have found that, with boilers having ample steam room, and where the fires have not been forced, the amount does not exceed 4 or 5 per cent.[2] In the trials now being described the firing was always very slow, and the Author is confident that any errors that may have been made in approximating the quantities of priming water are so insignificant that they cannot in any way seriously influence the results. The condensation in the steam mains was in most cases drained back by gravity to the boilers; but on the trials B, C, with a Woolf engine, it was drained into buckets, and on the first day's trial, when the jackets were shut off, it was not so freely drained as on the second day; and as the quantity of water, either condensed or deposited in the main, may be reasonably taken as the same percentage of the weight of steam delivered from the boilers on both days, the additional percentage drained on the second day has therefore been added to the first trial, and is taken account of in the calculations as priming water; hence the reason why it appears so great.

General Description of the Engines Tested.

Trial A.—A single-cylinder beam rotative engine, working one deep well and one high lift pump, direct from the beam. It was made by Messrs. Simpson and Co., of Pimlico, London. The cylinder, 45 inches in diameter by 5 feet 6 inches length of stroke, with its cover and base, is completely jacketed with boiler steam. The distribution of the steam is effected by separate slides at the top and bottom of the cylinder, with expansion plates, adjustable by hand, on the back. The valves are worked by eccentrics in the usual manner. A surface condenser is used, through which the suction water to the top pump passes. Three trials were made with this engine, each of which afforded the same result; one trial

[1] For the estimation of priming water by direct weight, see "Engineering," 28th December, 1877. At Düsseldorf experiments were made by dissolving Glauber's salts in the feed water and analysing the condensed steam. "Engineering," May 27th, 1881.

[2] Bulletin de la Société industrielle de Mulhouse, 1874. Also "The Steam Engine considered as a heat engine." By James H. Cotterill, M.A., 1878, Section 123.

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only is therefore given in the Tables. This engine had been at work about nine months before the trials were made; it was carefully examined, and the piston and valves were found to be tight and in good order.

Trials B, C.—A Woolf beam rotative engine working a deep well pump direct from the beam. It was made by Messrs. Simpson and Co., and had been at work about six months before the trials were made. The cylinders, 34 inches in diameter by 5 feet 6 inches length of stroke, and 22 inches in diameter by 3 feet 7 inches length of stroke, with their covers and bases, are jacketed with boiler steam. The steam is distributed by a long slide with the equilibrium passage in it, and expansion plates on the back, worked by eccentrics; there is a jet condenser, and the air-pump discharge was measured. Two trials were made with this engine, one trial with, and the other without, steam in the jackets; the results of both trials are given in the Tables.

Trials D, E, F.—A Woolf beam engine, driving a flour mill. It was made by Messrs. Simpson and Co. The cylinders, 38 inches in diameter by 5 feet 6 inches length of stroke, and 24½ inches in diameter by 3 feet 5 inches length of stroke, are steam-jacketed on the barrels only. The steam is distributed in the high-pressure cylinder by a slide-valve, with cut-off plates on the back, and in the low-pressure by a piston valve, all being worked by eccentrics. The steam is condensed in a surface condenser, the water being pumped through the tubes with a cold-water pump. Three trials were made with this engine, two with, and one trial without, the jacket. The results of all these are given in the Tables.

Trials G, H.—A horizontal Woolf tandem engine, unjacketed, very similar to that described by Mr. G. W. Sutcliffe,[1] as being the most generally adopted type in the factories of East and West Lancashire, except that there is a single slide on the high-pressure cylinder, with adjustable cut-off plates on the back, and the condenser and air-pump are horizontal in place of being vertical. It was made by Messrs. Pollit and Wigzell, of Sowerby Bridge, Yorkshire, the cylinders being 28½ inches in diameter and 15¾ inches in diameter, by 4 feet 3 inches length of stroke. The Author desires to express his thanks to the proprietors of the Gillingham Portland Cement Works for allowing this engine to be tested, and for giving him all the necessary facilities. Three trials were made, the air-pump discharge, in addition to the boiler feed, being measured in each case. The piston speed was about 680 feet per minute, and,

[1] Minutes of Proceedings Inst. C.E., vol. lviii., p. 227.

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owing to the light load on the engine, the steam was much wire-drawn. These trials are interesting as the type of engine is largely used in factories and mills. The results of two trials only are given, as during the first trial the engine had to be stopped for more work to be put on, which made the results liable to error.

Trial J.—A compound beam rotative engine, made by Messrs. Simpson and Co. It had been at work about six months before the trial. It is fitted with a steam receiver between the high- and low-pressure cylinders, on the system of Mr. E. A. Cowper, M. Inst. C.E.; these are 36 inches in diameter and 21 inches in diameter, by 5 feet 6 inches length of stroke respectively. The cranks are set at right angles, and two low-lift plunger pumps driven direct from each of the beams. Both cylinders and receiver, with the exception of the high-pressure cylinder and receiver covers, are jacketed with boiler steam. The steam is distributed by slide valves, one valve at the top and one at the bottom, with expansion plates on the back, the expansion in each cylinder being adjustable by hand. The valves are driven by a lay-shaft, which is worked from the crank-shaft by bevel gear. A jet condenser is used, and the air-pump discharge was measured. Two trials were made with this engine, but as they were exactly similar, the results of one only are given.

Trial K.—A single-acting Cornish engine, working a single-acting piston-pump direct from the beam. It was made by Messrs. Harvey and Co., of Hayle, Cornwall, in 1872. This engine has the usual Cornish steam, equilibrium, and exhaust valves, single-acting air-pump, and jet condenser; the cylinder is 68¼ inches in diameter by 8 feet length of stroke, and had only the barrel jacketed with boiler steam. The pump delivers its water on the up or steam stroke, so that the weights on the pump-pole are only sufficient to overcome the suction lift. This engine was subjected to a rigid test by Mr. Thomas Hack, M. Inst. C.E., engineer to the West Middlesex Waterworks, to ascertain if the piston, valves, &c., were tight and in good order before the trial; it is doing the highest duty at the West Middlesex Waterworks, and consequently burning the smallest quantity of fuel, compared with the other Cornish engines there, so that it may be taken as an example of one of the best engines of that type now at work. No further calculations other than those given in the Tables can be made for this engine, as the clearance spaces could not be correctly ascertained. The Author desires to express his best thanks to Mr. Hack for his kindness in allowing this engine to be tested, and

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for the trouble he took in personally superintending the trial, and ascertaining that the observations, which were all made under his directions and control, were carefully and thoroughly carried out.

Calculations of Heat used on Trial J.

The engine is compound, steam jacketed, with an intermediate receiver, and was running on the trial at an average speed of 23·98 revolutions per minute, and expanding the steam 13·61 times. The boiler-pressure p was 76 lbs. absolute, and the average indicated HP. 127·4. The total HP., or the power measured to the line of pressure due to the temperature of the condenser, was 138·30, 7·9 per cent., therefore, being lost through back pressure. The air-pump discharge was found to be 25·558 lbs. per stroke, the temperature of discharge f being 73°·4, and the injection water i 50°·0 Fahrenheit.

	lb.
Boiler delivery per stroke $M + M_p + M_j$	= 0·69693
Steam through cylinders per stroke M	= 0·58338
Priming water through cylinders per stroke M_p	= 0·02430
Effective condensation in jackets per stroke M_j	= 0·08925
Injection water per stroke II	= 24·95

The heat in thermal units passing through the engine per stroke is equal to

$$Q = M H + M_p h + M_j L \quad . \quad . \quad . \quad (1)$$

where H = total heat of steam measured from 32° F.

h = thermal units necessary to raise 1 lb. of water from 32° F to the temperature t.

L = latent heat of vaporisation.

$Q = 0·58338 \times 1176 + 0·0243 \times 278·58 + 0·08925 \times 897·45.$

$= 686·06 + 6·76 + 80·09 = 772·91.$

Now this quantity of heat Q, passing through the engine per stroke, must be equal to the heat rejected, $Q_1 + Q_2$, + the thermal equivalent of the indicated work W_i + radiation, the heat generated by the friction of the piston, valves, air-pump bucket, &c., being neglected.[1]

$$Q = Q_1 + Q_2 + W_i + R. \quad . \quad . \quad . \quad (2)$$

The rejected heat is made up of two parts, one part (that retained in the steam) passing away with the air-pump discharge Q_1 =

[1] "Théorie Méchanique de la Chaleur," par G. A. Hirn, vol. i., pp. 69–70.

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$(M + M_F) \times (f - 32)$, and the other being absorbed by the injection water $Q_2 = \Pi \times (f - i)$.

The indicated HP. in T U per stroke $W_i = 113{\cdot}55$, the radiation R is taken $= 22{\cdot}72$; $Q - Q_1 - Q_2 - W_i - R = 27{\cdot}65$, or, as compared with the total heat passing through the engine, a loss of $\frac{27{\cdot}6 \times 100}{772{\cdot}9} = 3{\cdot}57$ per cent.

Mr. Hirn has explained, as the reason of the heat found in the air-pump discharge being always less than it ought to be, as compared with the heat given by the boiler, and the amount used as work, that the air-pump abstracts, not only water, but the air contained in the steam; and the air, in passing away to the atmosphere, is saturated with vapour at the temperature of the hot well, and therefore a loss always exists; but on careful experiments the difference in the measurements between the boiler supply and the rejected heat ought not to exceed 5 per cent.[1] On this trial the condenser was in a very cold place, and the exhaust pipes were large and long, so that considerable radiation from them must have taken place, and might have been sufficient to account for the greater part of the loss.

It will be noticed that the heat given up by the condensation in the jackets has been taken as the latent heat of vaporisation, no heat being supposed to have been given up after the steam is condensed. On all the trials the arrangements for draining the jackets were so made that the moment the steam was condensed it was drained away, and the jackets could not become water-logged; the amount of priming water in the jacket-steam, as supplied from the boiler, has been deducted, and only the dry steam taken as effective. The radiation from the cylinders can be closely approximated by Mr. Hirn's method,[2] as follows:—

Let the steam be turned into the jackets when the engine is standing, and the condensed steam measured for a period of, say, four or six hours; the number of thermal units dissipated by radiation can then be obtained. With this engine this loss was not measured, and possibly was more than has been allowed, as the cylinders and the intermediate reservoir exposed large surfaces. Compared with the heat-units passing through the cylinder, Q, the radiation has been found to vary from 1 to 2½ per cent., and this percentage agrees with what has been taken by Messrs. Hirn and Hallauer for engines working with fairly high rates of expansion.

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[1] "Thermodynamique Appliquée," par G. A. Hirn, 1881, p. 25.

[2] "Bulletin de la Société industrielle de Mulhouse," 1878, p. 241.

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In taking a percentage of the total heat Q for the loss by radiation, allowance must be made for the speed of the piston, as with slow-running engines the loss is greater, and with fast-running ones less, assuming that both are equally well clothed.

Now that Q has been found, the T U used per indicated and per total HP. can be easily obtained,

I HP. = 127·4; T HP. = 138·3. Revolutions = 23·98.

$$\frac{Q \times 2 \times \text{revolutions}}{\text{I HP.}} = 291{\cdot}0 \text{ T U per I HP. per minute.}$$

$$\frac{Q \times 2 \times \text{revolutions}}{\text{T HP.}} = 268 \quad \text{,,} \quad \text{T HP.} \quad \text{,,}$$

Similarly the lbs. of dry steam used per I HP. and T HP. per hour can be found, H, or the total heat of steam at the boiler-pressure p, being 1176.

$$\frac{291 \times 60}{1176} = 14{\cdot}84 \text{ lbs. of dry steam per I HP. per hour.}$$

$$\frac{268 \times 60}{1176} = 13{\cdot}67 \quad \text{,,} \quad \text{,,} \quad \text{T HP.} \quad \text{,,}$$

Messrs. Donkin's coefficient = air-pump discharge $\times (f - i) \div$ I HP. = 225·1.

It will be observed that the temperature of the boiler feed does not come into the calculations of the thermal units used by the engine, the steam having been taken as produced from water at 32° Fahrenheit. By adopting this temperature, all engines are reduced to the same basis of measurement, and are independent of variations in the temperatures of the feed. Feed-heaters, economisers, or any other arrangement, only affect the efficiency of the boiler and the coal consumption, and have no influence on the quantity of heat passing through the cylinders, or on the efficiency of the engine.

In Table XI. will be seen the number of thermal units per indicated HP. per minute if the feed-water were drawn from the hot well and delivered into the boilers at that temperature, as it would be in ordinary work; and on this assumption the coal used for the engine per indicated HP. is based, and also the disposal of the heat $Q - Q_1$ through the engine, and for the trial under consideration,

Indicated work W_i	=	113·55 or 15·2 per cent.
Rejected heat and loss	=	81·8 ,,
Radiation	=	3·0 ,,

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From this it will be seen how small a quantity of the heat given by the boiler is transformed into useful work, and how large a quantity is wasted.

The results of Trial J are, the Author believes, almost, if not absolutely, the best ever obtained on a reliable and carefully made experiment, and where the heat delivered from the boiler was checked by the measurement of that rejected. On the previous day Messrs. Donkin's coefficient was 224·8, or practically the same when the jackets gave up the same quantity of heat, and a few days after Mr. E. A. Cowper, on a twenty-four hours' trial, found the feed-water to be 13·397 lbs. per indicated HP. per hour[1] (exclusive of the jacket supply, which was returned by gravity to the boilers and not measured), so that there can be no doubt as to the correctness of the results found on this trial.

The pressure at the end of admission, $p_1 = 64$ lbs., $w_1 = 0{\cdot}1506$, w being the weight of a cube foot of steam at a pressure p, and found by the formula of Zeuner, $\log w = {\cdot}9393 \log p - 2{\cdot}51858$.[2] The volume of the high-pressure cylinder at the point of cut-off, including the clearance space and the port = 2·9161 cubic feet, and $2{\cdot}9161 \times 0{\cdot}1506 = m_1 = 0{\cdot}4392$ lb. of steam as shown by the diagram.

To ascertain the amount of water in the cylinder, the weight of steam and water M_c, shut in by compression, must be added to the delivery from the boiler; $M + M_r + M_c = 0{\cdot}58338 + 0{\cdot}02430 + 0{\cdot}05913 = 0{\cdot}66681$ lb., and $0{\cdot}66681 - 0{\cdot}4392 = 0{\cdot}22761$ lb., which is the weight of water present in the cylinder at cut off. The whole of this quantity has not been condensed, as M_r + the water shut in the clearance is already in the form of water, and must be deducted, which leaves 0·17472 lb. of steam condensed during admission.

Mr. Combes in 1843 first noticed the condensation on admission, which he believed could be prevented by exposing the cylinder to a greater heat than that supplied by the boiler. The Author, however, believes Mr. D. K. Clark, M. Inst. C.E., was the first to make experiments[3] as to the relative proportion between the weight of water supplied to the boiler, and that as shown by the diagram, and to note the large amount of condensation that always takes place on admission, and which increases with the rate of expansion.

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[1] "Engineering," December 9, 1881, p. 575.

[2] "Théorie Mechanique de la Chaleur," par Dr. G. Zeuner, traduit par Arnthal et Cazin, 1869, p. 286.

[3] Institution of Mechanical Engineers. Proceedings, 1852, p. 109.

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From the results given on Table XII. it will be seen to vary in the experiments from 30 to 50 per cent.; the amount of steam has been calculated for the other parts of the stroke, in a similar manner to that just described, and the percentages of water present in the cylinder will be found in the Tables.

Exchanges of heat between the steam and the Cylinder Walls, and the loss due to the Cooling Action of the Condenser.

This subject has been a vexed one for many years, and has greatly occupied the attention of theorists and engineers, the opinions expressed having been very varied as to the extent and nature of the exchanges and losses. Mr. Hirn and those who have experimented with him, or under his immediate guidance, have fully explained, by the results obtained from many trials, made under the most varied conditions, the actions of the cylinder walls, and the great loss that exists during exhaust through the cooling action of the condenser. Professor Cotterill, Assoc. M. Inst. C.E., has also in his work on "The Steam Engine considered as a heat Engine," entered into the details of the question, and defined these actions, and has shown that, although the period of time during which admission takes place is so short, a very great amount of initial condensation can and does exist. Dr. Zeuner, in a Paper published in "Der Civil-ingenieur" in 1875,[1] expressed the belief that wire-drawing steam partly accounted for the results obtained by experiment, and which were attributed to the actions of the walls; and last year (1881) he published an article in the same paper[2] attributing the condensation and re-evaporation that takes place during the stroke, to water remaining after exhaust. Mr. Hirn and Mr. Hallauer have both written articles in the "Bulletin de la Société industrielle de Mulhouse," refuting that opinion, and have shown in the most convincing manner, that in their experiments water could not remain in any quantity after exhaust, and even if it did, it could not be sufficient to cause those actions which are produced during the passage of the steam through the cylinder. In the engines tested by the Author, which were all well designed, water could not have remained, and, except in the case of the B trial, the amount of the priming-water could not have been great; nor was any water apparently present in taking the diagrams, except in the trial just mentioned; therefore the condensations and evaporations must mainly, if not entirely, have been due to the action of

[1] Minutes of Proceedings Inst. C.E., vol. xl., p. 283.
[2] "Calorimetrische untersuchung der Dampfmaschinen."

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the cylinder sides. In all engines the action of the walls is very energetic during the period of admission, as they expose a surface which is of a lower temperature than that of the in-flowing steam, and condensation must take place; and even in compound engines, where the high-pressure cylinder is not in direct communication with the condenser, this cooling action takes place. The heat given up by this must almost entirely be absorbed by the walls; and one part of it is given out by them during expansion, and as a result some of the water present in the cylinder at the point of cut-off is evaporated; this will be observed from Table XII., where the percentage of water at the point of exhaust is always less than at the end of admission. For trial J, the water present at the end of admission was 34·1 per cent., and at exhaust 19·9 per cent., the difference having been evaporated during expansion, the heat necessary for this being obtained from the cylinder-walls. Referring to the indicator diagrams, the index γ of the constant PV^{γ} will be seen on each high-pressure curve; it is in every case less than that of the saturation, or of the hyperbolic curve; its value has been found from the formula[1] $\gamma = \frac{\log p_1 - \log p_2}{\log v_2 - \log v_1}$, where V_1 and V_2 are the volumes at cut-off and at the toe of the high-pressure diagram; this again shows generally that evaporation has taken place during expansion. If γ is taken out for different parts of the stroke, it will be seen to vary, as the curves are all flatter towards the end of the expansion, where the steam is more exposed to the action of the walls, and consequently evaporation is increased.

The Author has not been able to make any experiments with superheated steam, but some elaborate trials have been made by Mr. Hirn, and in one instance where the steam was superheated to a temperature of 419° Fahrenheit, from an absolute boiler pressure of 71 lbs., five expansions being made, the value of γ was 1·09, which gives a remarkably low curve. In this case the steam gave up heat to the cylinder walls during expansion. Much importance would attach at first sight to the value of γ, but as a large variation in the heat absorbed only produces a small alteration in γ, the figure is only of general interest;[2] it is, however, always worth while to find its value, and when doing so care should be taken to add the exact volume of the clearance, and to

[1] "Recherches expérimentales et analytiques sur les machines à Vapeur." M. G. Leloutre, 1873, p. 172.

[2] "The Steam Engine considered as a heat engine." By James H. Cotterill, M.A., 1878, section 55.

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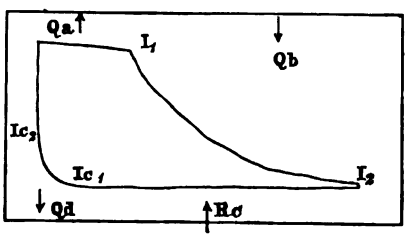
ascertain that the piston and valves are tight, and that the indicator-barrel travels uniformly with the motion of the crosshead, as many diagrams are taken with a false motion, and consequently are worthless. The other part of the heat given up on admission is rendered by the walls to the steam during exhaust, and is entirely wasted; this loss, called R c by Messrs. Hirn and Hallauer,[1] is due to the cooling action of the condenser, and in some engines (more especially those that are working without steam jackets) amounts to a very large percentage of the total heat Q, passing through the cylinder. The evaporation during expansion is of value, as it increases the pressure, and consequently the work done; but the heat absorbed during exhaust, R c, is pure loss; not only is the heat wasted, but the evaporation due to it tends to increase the work of back-pressure and to cool the cylinder walls.

Now in any engine where a permanent regime has been reached, an equality must exist between these exchanges of heat, and it is possible by very simple calculations to ascertain the value of each exchange.

Let Fig. 1 represent an indicator diagram placed inside a cylinder, the arrows pointing in that direction in which the transfer of heat generally takes place, and calling

FIG. 1.



Q a = heat given up by the steam during admission;
Q d = " " " " compression;
M_1 L = " " by condensation in jacket;
Q b = heat absorbed by the steam during absolute work of expansion;
R c = heat absorbed during exhaust;
R = " " by radiation,

the following equation is obtained—

$$Q a + Q d + M_1 L = Q b + R c + R \quad . \quad . \quad . \quad . \quad (3)$$

[1] "Moteurs à Vapeur," par O. Hallauer, 1877. Minutes of Proceedings Inst. C.E., vol. xlvii., p. 376.

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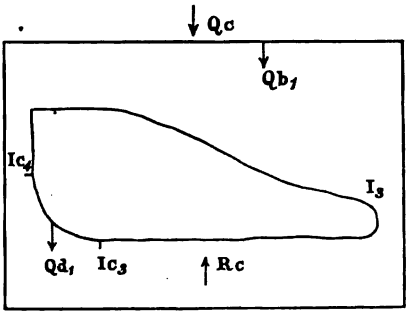
as the heat given up to the walls must be equal to the heat given from them.

This law holds good for both simple and compound engines, but with the latter, the heat absorbed by the steam during the high-pressure exhaust will be called Q c, in place of R c which denotes the loss due to the cooling action of the condenser.

If it be supposed that Fig. 1 represents the high-pressure cylinder, and that Q c comes down with the exhaust and passes into the low-pressure cylinder, then the following diagram (Fig. 2), represents

FIG. 2.



the exchanges of heat that must take place in the low-pressure cylinder.

It follows that—

$$Qd_1 + Qc + M_J L_1 = Qb_1 + Rc + R_1 \quad . \quad . \quad . \quad (4)$$

where the suffix $_1$ refers to the low-pressure cylinder, and these equations 3 and 4 generally express the exchanges of heat in any engine during the stroke.

The value of Qa, the heat given up on admission, will now be found from the general formula of Professor Cotterill.[1]

Heat expended = internal work + external work, and adapting it to find Qa, it becomes—

$$Q\,a = Q - M_J L - I_1 - W a \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where Wa = the absolute work of admission, and I_1 = the total internal heat of the mixture of steam and water at the end of admission.

[1] "The Steam Engine considered as a heat engine." James H. Cotterill, M.A., 1878, section 14.

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The internal heat, I, of a mixture of steam and water, is found from the formula

$$I = Mh + m\rho,$$

where M = the total weight of the mixture;
m = the weight of steam;
ρ = the internal heat of evaporation;
h having the same value as before.

When compression is used, the heat $Q - M_1L$, supplied by the boiler, meets with the internal heat Ic_2 at the end of compression, and the formula becomes

$$Qa = Q - M_1L + Ic_2 - I_1 - Wa \quad . \quad . \quad . \quad . \quad (5a)$$

For trial J it will be seen from Table 6 that $Qa = 147{\cdot}89$. Mr. Hirn gives the following simple formula for finding Qa—

$$Qa = (M + m_{c_2} - m_1)\, L_1$$

which is sufficiently correct for all practical purposes; but by adopting formula $5a$, a perfect check on the calculations can be obtained.

If Qa be ascertained from Mr. Hirn's formula for trial J, it will be found equal to 158·25 T U, or almost the same as by $5a$, for there is only a difference of 1·3 per cent. of the total heat Q. When the pressure at the end of admission is equal to that of the boiler, it can be easily shown that both the formulæ give the same results; or, in other words, that the total heat of the steam at the end of admission is equal to that of the boiler steam.

Qd, the heat given up or abstracted during compression in the high-pressure cylinder, has next to be found by the following formula

$$Qd = Ic_1 - Ic_2 + Wd \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where Wd is the absolute work of compression, and for trial J $Qd = +\,37{\cdot}32$. On reference to Table VII., where the value of Qd is given, it will be seen that on two trials it was a negative quantity. This shows that during compression heat was abstracted from the walls.

Qb = heat abstracted during expansion, is obtained from the equation

$$Qb = I_2 - I_1 + Wb \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Wb being the absolute work of expansion in the high-pressure cylinder, and I_1 I_2 the total internal heat at the commencement

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and end of expansion in the high-pressure cylinder; for trial J $Qb = 97{\cdot}51$.

The value of Qc, the heat absorbed by the steam passing from the high-pressure cylinder during the exhaust, can now be obtained from formula 3, substituting Qc for Rc; $M_J\ L_H$ the heat given up by the high-pressure jacket, and R H the external radiation, being found in Table IX.

$Qc = Qa + Qd + M_J\ L_H - Qb - R_H$, and for trial J, $Qc = 147{\cdot}89 + 37{\cdot}32 + 32{\cdot}43 - 97{\cdot}51 - 7{\cdot}00 = 113{\cdot}13$ T U, as shown in Table IX.

Now to find the exchanges that take place on passing from the high-pressure through the receiver and low-pressure cylinder, and the loss at exhaust Rc, formula 4 must be taken; in a receiver engine corrections have to be made in Qc, for the heat given up in the receiver jacket, and the external radiation from it.

Qd_1 is found by formula 6 the same as Qd.

$Qd_1 = Ic_3 - Ic_4 + Wd_1$, and is for trial J $= -6{\cdot}69$. It will be noticed in Table VII. that in all the trials made by the Author the value of Qd_1 was a negative quantity, as the compression was not sufficient to give up heat to the walls.

Qb_1 will next be found from equation 7; but a correction must be made to I_2, for the work of expulsion from the high-pressure cylinder must be added to it, and the internal heat Ic_1 at the beginning of compression deducted from it, and, as it meets Ic_4 on entering the low-pressure cylinder, it also must be added.

$$Qb_1 = I_3 - (I_2 - Ic_1 + Ic_4 + We) + Wb_1 \quad . \quad . \quad . \quad (8)$$

where Wb_1 = the absolute work of expansion in the low-pressure cylinder;

and We = the absolute work of expulsion from the high-pressure cylinder;

for trial J, $Qb_1 = 49{\cdot}99$.

$Qc = 113{\cdot}13$, and making the necessary corrections for the heat received from the jacket, and that lost during its passage through the receiver by radiation, it becomes

$$Qc_1 = 116{\cdot}83.$$

Rc can now be found from formula 4.

$Rc = 116{\cdot}83 - 49{\cdot}99 - 6{\cdot}69 + M_J\ L_1 - R_1 = 88{\cdot}39$, which is equal to 11·4 per cent. of the total heat passing through the cylinders. This is a pure loss, as the heat passes away with the exhaust steam to the condenser.

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There is a direct way of calculating Rc from the rejected heat found in the air-pump discharge as follows:—

$$\left.\begin{array}{l} \text{for simple engines} \quad Q_1+Q_2 = I_2 - Ic_1 + We + Rc, \\ \text{for compound engines} \quad Q_1+Q_2 = I_3 - Ic_3 + We_1 + Rc, \end{array}\right\} \quad (9)$$

where We = the absolute work of expulsion from the high-pressure cylinder,

and We_1 = the absolute work of expulsion from the low-pressure cylinder,

which formula is adopted by Messrs. Hirn and Hallauer,[1] and given by Professor Zeuner;[2] but, as it will be seen by formula 2,

$$Q_1 + Q_2 = Q - Wi - R;$$

therefore both Rc and Qc can be found directly from the heat from the boiler, which method of calculating them is preferable, as the heat Q is obtained by direct measurement, and $Q_1 + Q_2$, the rejected heat, only by inference, obtained by experiments with slot gauges; formula 9 then becomes

$$\left.\begin{array}{l} Rc \text{ or } Qc = Q - Wi - We - I_2 + Ic_1 - R \quad . \quad . \\ \qquad Rc = Q - Wi - We_1 - I_3 + Ic_3 - R \quad . \quad . \end{array}\right\} \quad (10)$$

In Tables IX. and X. Qc and Rc are calculated by this formula, and, if the figures are correct, they must check the values previously found. These formulæ 10 are only an adaptation of the general formula given by Professor Cotterill. Heat expended = internal work + external work; and it is evident that, whether Rc is calculated from the rejected heat, from the heat given by the boiler, or from formula 4, the results should be the same.

It will be seen from these practical results that to consider the cylinder as impermeable to heat, and that the steam enters the cylinder and expands without giving up to, or receiving heat from, the walls, leads to an erroneous theory of the action of the steam engine; and that only from deductions drawn from actual trials can correct conclusions be arrived at. Mr. Hirn has expressed these views[3] many times, though in nearly all the theoretical works on the steam engine, evaporation of water contained in the steam is supposed to take place during admission, and condensation during expansion, the reverse of this being actually the case.

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[1] "Thermodynamique appliquée," par G. A. Hirn et O. Hallauer, 1881.

[2] "Calorimetrische untersuchung der Dampfmaschinen." Der Civilingenieur, 1881.

[3] "Theorie Mechanique de la Chaleur." G. A. Hirn, 1876, vol. ii., chap. i.

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The Author has been unable to make a more extended series of experiments on the efficiency of various types of engines. He has only had the opportunity of testing those with which he has been professionally connected, except the Cornish and the tandem engines. The trial A of the single-cylinder engine did not give such good results as might have been obtained had a higher boiler-pressure been used, and a greater piston speed. The number of expansions made (6·85) is also unfavourable for economy, as in a single cylinder experience has shown that the best results are obtained with from five to six expansions. The other single-cylinder engine tested was the Cornish, trial K, and the Author believes it is the only time that the heat used by an engine of that design has been thoroughly measured. The trial was a tedious one to carry out, as the stroke had to be ascertained, and the mean piston-speed, as given in the Table, was obtained from the average of 3,978 readings of the length of stroke, as taken from the positions of the crossheads during the pauses. The slip on the pumps could not be measured, but it may be taken as 2½ per cent. of the theoretical capacity, and the difference between the indicated and the pump HP., measured from the water lifted, was 20·7 per cent. of the indicated power. Taking the thermal units given up by best Welsh coal carefully stoked as 11,000, the duty of the engine was 68·6 million foot-lbs., raised with 1 cwt. of coal, and the Author believes this is a far higher duty than is being done at the present time by the average of engines of that class.

Trials B, C. These trials are interesting, as showing the great loss that existed when the steam main was not thoroughly drained, and the jackets shut off, 519·5 T U being used in that case against 338·8 T U, when the main was better drained, and the jackets were on. The water present at the cut-off was 51·1 per cent. against 40·8 per cent., and at the low-pressure toe 38·8 per cent. against 8·7 per cent., the loss by the cooling action of the condenser (Rc) being reduced, in the latter case, when the jackets were on, from 24·4 per cent. to 3·1 per cent.

The Author regrets that he did not make another experiment without the jackets, but with the steam main thoroughly drained. This would have allowed a better comparison to be made of the efficiency due to the jackets. In the next trials, D, E, F, it will be noted that the best result, 341·8 T U, was obtained when 8·3 per cent. of steam passed through the jackets, against 348·1 when only 7·1 per cent. passed, the water present at the toe of the low-pressure diagram being 14·3 per cent. against 17·5 per cent., and the loss due to Rc 9·4 per cent., instead of 11·3 per cent.

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When the jackets were shut off 378·1 T U were used, or a loss of 10½ per cent., the loss due to Rc being 22·5 per cent. Had the cylinders been better jacketed, that is, the covers and bottoms in addition to the barrels, the loss through shutting off the jackets would undoubtedly have been greater in proportion. With the tandem engine unjacketed, trials G, H, it will be seen that there was a saving of 3½ per cent. when the indicated HP. was raised from 120·3 to 149·75; but even with the latter power the engine was running very light, and would have done better with a heavier load. The details of trial J have been described, and need not be further alluded to. Had these engines been driving high-lift pumps of, say, 150 to 200-feet head, and assuming the loss between the pump HP. and the indicated HP. to be 20 per cent., the feed-water drawn from the hot well, and the jacket drains circulating by gravity, 116,000,000 lbs. would have been raised 1 foot high with 1 cwt. of pure Welsh coal, giving out 11,000 thermal units per lb. in actual work.

Table XI. has been made by taking the T U used by the engines, on the assumption that the feed-water was drawn from the hot well, and that a uniform quality of coal was used in the furnaces.

The Author has taken the value of coal as 11,000 units,[1] that amount being frequently obtained with large heating surfaces and slow firing; the latent heat of steam at 212° being 966, 11,000 T U is equal to 11·4 lbs. of water evaporated from and at 212°. In this Table it will be seen that this engine would use 1·53 lb. of coal per HP. per hour, which is almost the same as it was found to do on a trial made by Mr. John Taylor, M. Inst. C.E., in September 1881.[2] On that trial the feed was cold, and not drawn from the hot well, which accounts for the small additional amount of coal, 0·02 lb. per HP. per hour being burnt over the quantity, 1·53 lb. given in the Table.

It will be seen from these results that great advantage was in each case gained by the jackets being at work, and that they were productive of economy. On the trials made at Mulhouse in 1878,[3] the advantage obtained by a steam-jacketed Corliss engine over an exactly similar Corliss engine unjacketed was 30·5 per cent. in favour of the jacket, the piston-speed being 400 feet a minute. On the B and C trials the gain was 34¾ per cent. by using jackets

[1] Messrs. Donkin obtained nearly 12,400 T U with Powell's Duffryn coal. "Engineering," November 3, 1871.

[2] "Engineering," vol. xxxii., p. 575.

[3] Minutes of Proceedings Inst. C.E., vol. lviii., p. 388.

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and draining the steam main; and on D, E, F trials it was seen how the better discharge from the jacket increased the efficiency, and how 10½ per cent. were lost by their being shut off. The action of the jackets is easily explained; it generally reduces the amount of initial condensation, increases the work done during expansion, and reduces the loss Rc at exhaust. Care ought, however, to be taken in comparing experiments made with and without jackets, as in some cases the jackets are only air-traps, and in others they are insufficiently drained, and get waterlogged. They ought to be always supplied by steam entirely distinct from that going into the cylinders, and where care will be taken to prevent air collecting, the drains ought to be in circulation with the boilers. Professor Cotterill states in his work before alluded to (page 266), that "the advantage derived from jackets varies according to circumstances; if the terminal pressure in the high-pressure cylinder of a compound engine be high as compared with the back pressure, so as to be decidedly above the critical value, the range of temperature will be small, and no considerable liquefaction will probably occur even though there be no jacket. And if the terminal pressure approach the back pressure so that the tendency to liquefaction is strong, the jacket may probably be of little advantage; but if, on the other hand, the terminal pressure is a little below the critical value, the amount of heat necessary to prevent an accumulation of water will be very small, and a jacket may be expected to prove of material advantage. The influence of the speed of piston on the action of the sides cannot at present be estimated; but the effect of speed mainly depends upon whether the condensation or the evaporation is most influenced, and it is not inconceivable that under certain circumstances an increase of speed may be accompanied by an increase, instead of a diminution, in the action of the sides."

Jackets must do good, and to make economical engines every part ought to be thoroughly jacketed, the steam pressure high, and, if necessary, three or even four cylinders used to carry out a high rate of expansion, so as to have a small range of temperature in each cylinder, and compression ought to be adopted, as it diminishes the action of the sides.[1]

The Author trusts that this Paper will be received as an endeavour to introduce heat as a unit of measurement of the efficiency

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[1] Minutes of Proceedings Inst. C.E., vol. xlii., p. 330. Also "The Steam Engine considered as a heat engine," by James H. Cotterill, M.A., 1878, section 114.

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of engines, in place of the unmeaning unit at present adopted, and to induce engineers to make further trials with a view to ascertain in practice the most economical type of engine. In conclusion, he tenders his best thanks to Mr. James Simpson, M. Inst. C.E., for the many valuable suggestions made by him with reference to these trials, and especially to those experiments made to ascertain the coefficients of the discharge from the slot gauges; and also to Mr. T. H. Houghton, Stud. Inst. C.E., for the great amount of care and trouble taken by him in checking the numerous calculations, and for his personal assistance during the trials themselves.

The Paper is illustrated by several diagrams, from which Plate 11 and two woodcuts have been prepared.

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APPENDIX.—TABLE I.—DATA.

——	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.
Date of trial . . .	Feb. 1881	Aug. 1881	Aug. 1881	Dec. 1881	Dec. 1881	Dec. 1881	Feb. 1882	Feb. 1882	Oct. 1881	Nov. 1881
Type of engine . .	Single Cylinder Beam	Compound Woolf Beam		Compound Woolf Beam			Compound Horizontal Woolf Tandem		Compound Receiver Beam	Cornish
Time running . . .	H. M. 6 46	H. M. 6 0	H. M. 10 0	H. M. 10 0	H. M. 11 0	H. M. 10 0	H. M. 3 30	H. M. 6 0	H. M. 6 0	H. M. 10 30
Total number of revolutions from counters	5,938	6,421	11,772	20,238	22,584	20,710	16,895	29,345	8,632	8,090 strokes
Revolutions per minute	14·62	17·84	19·62	33·73	34·22	34·52	80·45	81·51	23·98	12·84
Indicated HP. . . .	101·79	75·9	75·2	267·86	267·94	267·91	120·30	149·75	127·40	146·02
Total HP.	115·04	87·36	85·09	284·25	282·55	288·69	147·39	177·32	138·30	183·62
Feed to boilers deducting steam-pipe drains . . lbs.	15,840	12,978	13,585	49,182	53,218	52,535	9,400	19,355	12,032	38,264
Temperature of feed-water	66°	63°	63°·2	47°·3	48°·45	48°	54°	54° 04	59°·05	51°·05
Temperature of injection water . *i*	..	54°·57	59°·99	..	..	..	53°·1	53°·3	50°	50·45
Temperature of air-pump discharge. *f*	70°	98°·57	85°·49	51°·50	54°	53°	98°·56	107°·54	73°·4	86°·2
Air-pump discharge per minute . lbs.	..	784·1	803·4	..	..	..	952	940	1,225·8	1,662
Water drained from jackets . . lbs.	648	Jackets not in use	1,345	3,502	4,284	Jackets not in use	No jackets on cylinders		1,605	1,732·5
Percentage of priming water in steam . .	4	8½	2½	2½	2½	2½	4	4	4	3
Height of barometer during trial in inches	29·60	29·82	29·73	30·25	29·8	29·75	30·67	30·67	30·20	30·04

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TABLE II.—VOLUMES, &c.

——	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.
Volume of high-pressure cylinder in cubic feet . . . . . V_2	60·346	9·361		11·053			5·627		13·02	198·18
Volume of high-pressure cylinder clearance in cubic feet . . . . . V_o	1·000	0·300		·0·564			0·395		0·2151	..
Volume of low-pressure cylinder in cubic feet V	..	34·67		43·077			18·601		38·66	..
Volume of low-pressure cylinder clearance in cubic feet . . . . . V_{o_1}	..	0·908		1·431			1·018		1·035	..
Volume at end of admission in cubic feet . . . . . V_1	8·953	3·823	2·257	4·617	4·654	5·722	1·708	1·685	2·916	..
Total number of expansions . . .	6·85	9·30	15·76	9·64	9·56	7·77	11·485	11·645	13·61	..
Weight of steam and water through cylinder per stroke . . . $M + M_P$	lb. 1·2798	lb. 1·01059	lb. 0·51987	lb. 1·13074	lb. 1·08574	lb. 1·26834	lb. 0·27818	lb. 0·32978	lb. 0·60768	lbs. 4·52194
Weight of priming water through cylinder per stroke . . . . . M_P	·05335	0·08538	0·01300	0·02827	0·02714	0·03178	0·01113	0·01319	0·02430	0·13566
Weight of steam condensed in jackets per stroke . . . . . M_J	0·05400	..	0·05713	0·08436	0·09284	..	..	..	0·08925	0·20773
Weight of steam and water shut in high-pressure cylinder clearance $m\,c$	0·01440	0·01800	0·02200	0·08109	0·08109	0·07531	0·03459	0·04146	0·05913	..
Total weight of steam and water in high-pressure cylinder per stroke $M + M_P + m\,c$	1·29420	1·02859	0·54187	1·21183	1·16683	1·34365	0·31277	0·37124	0·66681	..
Weight of steam at end of admission m_1	0·72700	0·50250	0·32043	0·7560	0·72647	0·88698	0·17935	0·20907	0·43920	..
" " " " high-pressure stroke . . . . . m_2	0·92632	0·66720	0·44339	0·91659	0·91544	0·96771	0·23308	0·27644	0·51789	..
Weight of steam and water shut in clearance of low-pressure cylinder. $m\,c_1$	..	0·03070	0·03000	0·01212	0·01022	0·01716	0·02178	0·02178	0·01680	..
Total weight of steam and water in low-pressure cylinder $M + M_P + m\,c_1$	..	1·04129	0·54987	1·14286	1·09596	1·2855	0·29996	0·35156	0·62448	..
Weight of steam at end of low-pressure stroke . . . . . m_3	..	0·68713	0·50165	0·94268	0·93912	0·88274	0·22110	0·25897	0·50015	..
Weight of air-pump discharge per stroke . . . . $n + M + M_P$	..	21·980	20·475	..	..	..	5·017	5·766	25·558	129·44

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TABLE III.—WORK EXPRESSED IN THERMAL UNITS PER STROKE.

——	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.
Absolute work of full admission . W a	55·16	36·13	21·89	58·88	60·53	73·23	13·41	14·87	37·49	..
„ „ „ total expansion in high-pressure cylinder . . . W b	117·00	89·61	38·48	57·89	56·47	50·68	19·07	23·88	54·61	..
Work of expulsion from high-pressure cylinder . . . . . W e	21·56	20·33	15·58	25·44	26·37	24·3	9·89	12·08	31·47	..
Work of compression in high-pressure cylinder . . . . . W d	1·80	1·94	1·49	7·94	7·65	8·55	2·44	2·76	7·14	..
Absolute work in low-pressure cylinder W b_1	..	56·98	53·27	98·23	95·13	89·26	22·12	26·67	72·69	..
Work of expulsion from low-pressure cylinder . . . . . W e_1	..	16·90	12·18	10·84	9·88	13·34	8·64	9·47	12·03	..
Work of compression in low-pressure cylinder . . . . . W d_1	..	2·59	2·49	1·05	0·88	1·10	1·67	1·84	0·60	..
Total absolute work of expansion W b + W b_1 − W e	117·00	76·26	76·17	130·68	125·23	115·64	31·30	38·47	95 83	..
Indicated work in high-pressure cylinder . . . . . W i (H. P.)	148·80	53·47	43·30	83·39	82·98	91·06	20·14	23·91	53·49	486·07
Indicated work in low-pressure cylinder . . . . . W i (L. P.)	..	37·49	38·60	86·34	84·37	74·82	11·82	15·36	60·06	..
Total indicated work . . . . W i	148·80	90·96	81·9	169·73	167·35	165·88	31·96	39·27	113·55	486·07
Radiation . . . . . R	15·00	16·90	16·90	17·00	17·00	17·00	3·20	4·00	22·72	48·32

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TABLE IV.—HEAT PASSING THROUGH ENGINE PER STROKE. FORMULA 1.

		A.	B.	C.	D.	E.	F.	G.	H.	J.	K.
Thermal units from boiler as dry steam	$M \times H$	1,431·0	1,083·05	594·0	1,299·12	1,248·27	1,458·41	314·73	373·05	686·06	5,115·10
,, ,, as priming water	$M_P \times h$	13·2	22·20	3·4	8·09	7·84	9·21	3·20	3·77	6·76	33·34
,, ,, by condensation in jackets	$M_J \times L$	49·6	..	51·8	75·23	82·32	..	..	..	80·09	191·18
Total heat through engine per stroke	Q	1,493·8	1,105·25	649·2	1,382·44	1,338·43	1,467·62	317·95	376·82	772·91	5,339·62
VERIFICATION OF Q BY FORMULA 2.											
Heat retained in condensed steam $(M+M_P)(f-32)$	Q_1	..	67·27	27·8	..	..	..	18·51	24·91	25·16	245·08
Heat absorbed by injection water $\Pi\ (f-t)$	Q_2	..	922·68	508·9	..	..	..	256·32	294·87	583·83	4,465·85
Indicated work in thermal units	w_I	..	90·96	81·9	..	..	..	31·96	39·27	113·55	486·07
Radiation	R	..	16·90	16·9	..	..	..	3·20	4·00	22·72	48·32
Error		..	7·44	13·7	..	..	..	7·96	13·77	27·65	94·30
			1,105·25	649·2	..	..	..	317·95	376·82	772·91	5,339·62
Percentage of error to total heat Q		..	0·67	2·1	..	..	..	2·5	3·6	3·57	1·76

TABLE V.—INTERNAL HEAT of STEAM and WATER contained in CYLINDERS.

		A.	B.	C.	D.	E.	F.	G.	H.	J.	K.
At point of cut-off	I_1	915·60	683·60	408·08	951·81	913·1	1,092·7	227·3	268·98	540·80	..
At end of high-pressure stroke	I_2	1,035·30	799·70	496·23	1,059·03	1,047·8	1,134·6	264·93	315·77	583·70	..
,, low ,, ,,	I_3	..	737·30	539·87	1,036·67	1,026·33	953·67	244·29	287·19	546·82	..
At beginning of compression in high-pressure cylinder	$I c_1$	12·88	19·27	15·21	87·02	87·02	80·75	37·07	44·53	63·54	..
At end of compression in high-pressure cylinder	$I c_2$	15·32	19·45	23·83	59·61	51·10	61·06	27·71	34·25	33·36	..
At beginning of compression in low-pressure cylinder	$I c_3$	..	26·44	21·93	9·05	8·44	13·88	20·86	20·86	10·60	..
At end of compression in low-pressure cylinder	$I c_4$	..	32·95	31·88	12·84	10·81	18·30	23·26	23·26	17·89	..

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TABLE VI.—HEAT GIVEN UP TO CYLINDER WALLS DURING ADMISSION. FORMULA 5a.

——	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.
Heat through engine per stroke . . . . . Q	1,493·80	1,105·25	649·20	1,382·44	1,338·43	1,467·62	317·95	376·82	772·91	..
Heat given up in jackets M_J L	49·60	..	51·80	75·23	82·32	..	..	..	80·09	..
	1,444·20	1,105·25	597·40	1,307·21	1,256 11	1,467·62	317·95	376·82	692·82	..
Internal heat of steam and water shut in high-pressure clearance . . I c_2	15·32	19·45	23·83	59·61	51·10	61·06	27·71	34·25	33·36	..
	1,459·52	1,124·70	621·23	1,366·82	1,307·21	1,528·68	345·66	411·07	726·18	..
Absolute work of admission . . . . W a	55·16	36·13	21·89	58·88	60·53	73·23	13·41	14·87	37·49	..
Internal heat of steam and water at end of admission . . . . . I_1	915·60	683·60	408·08	951·81	913·10	1,092·70	227·30	268·98	540·80	..
Heat given up on admission . . . . Q a	488·76	404·97	191·26	356·13	333·58	362·75	104·95	127·22	147·89	..
	1,459·52	1,124·70	621·23	1,366·82	1,307·21	1,528·68	345·66	411·07	726·18	..

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TABLE VII.—HEAT GIVEN TO CYLINDER WALLS DURING COMPRESSION. FORMULA 6.

——	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.
Internal heat of steam and water shut in high-pressure cylinder by compression $I c_1$	12·88	19·27	15·21	87·02	87·02	80·75	37·07	44·53	63·54	..
Work of compression in high-pressure cylinder in thermal units . . . $W d$	1·80	1·94	1·49	7·94	7·65	8·55	2·44	2·76	7·14	..
	14·68	21·21	16·70	94·96	94·67	89·30	39·51	47·29	70·68	..
Internal heat at end of compression in high-pressure cylinder . . . . $I c_2$	15·32	19·45	23·83	59·61	51·10	61·06	27·71	34·25	33·36	..
Heat given up to high-pressure cylinder walls during compression . . . $Q d$	−0·64	1·76	−7·13	35·35	43·57	28·24	11·80	13·04	37·32	..
Internal heat shut in low-pressure cylinder by compression . . . . . $I c_3$	..	26·44	21·93	9·05	8·44	13·88	20·86	20·86	10·6	..
Work of compression in low-pressure cylinder in thermal units . . . . . $W d_1$	..	2·59	2·49	1·05	0·88	1·10	1·67	1·84	0·6	..
	..	29·03	24·42	10·10	9·32	14·98	22·53	22·70	11·20	..
Internal heat at end of compression in low-pressure cylinder . . . . . $I c_4$	..	32·95	31·88	12·84	10·81	18·30	23·26	23·26	17·89	..
Heat given up to low-pressure cylinder walls during compression . . . $Q d_1$	..	− 3·92	− 7·46	− 2·74	− 1·49	− 3·32	− 0·73	− 0·56	− 6·69	..

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TABLE VIII.—HEAT ABSORBED BY STEAM DURING EXPANSION. FORMULA 7.

——	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.
Difference in internal heats in high-pressure cylinder . . . . . $I_2 - I_1$	119·7	116·10	88·15	107·22	134·70	41·90	37·63	46·79	42·9	..
Absolute work of total expansion in high-pressure cylinder . . . . . $W b$	117·0	39·61	38·48	57·89	56·47	50·68	19·07	23·88	54·61	..
Heat absorbed during expansion in high-pressure cylinder . . . . . $Q b$	236·7	155·71	126·63	165·11	191·17	92·58	56·70	70·67	97·51	..
Internal heat at end of low-pressure stroke I_2	..	737·30	539·87	1,036·67	1,026·33	953·67	244·29	287·19	546·82	..
Internal heat shut in high-pressure cylinder by compression . . . . . $I c_1$	..	19·27	15·21	87·02	87·02	80·75	37·07	44·53	63·54	..
Work of total expansion in low-pressure cylinder . . . . . $W b_1$	..	56·98	53·27	98·23	95·13	89·26	22·12	26·67	72·69	..
	..	813·55	608·35	1,221·92	1,208·48	1,123·68	303·48	358·39	683·05	..
Internal heat of steam shut in low-pressure clearance . . . . . $I c_4$	..	32·95	31·88	12·84	10·81	18·30	23·26	23·26	17·89	..
	..	780·60	576·47	1,209·08	1,197·67	1,105·38	280·22	335·13	665·16	..
Internal heat at end of high-pressure stroke + work of expulsion from high-pressure cylinder . . . . . $I_2 + W e$	..	820·03	511·81	1,084·47	1,074·17	1,158·90	274·82	327·85	615·17	..
Heat absorbed during low-pressure stroke $Q b_1$	..	−39·43	64·66	124·61	123·50	− 53·52	5·40	7·28	49·99	..

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TABLE IX.—EXHAUST WASTE FROM HIGH-PRESSURE CYLINDER. BY DIRECT MEASUREMENT.

—	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.
Internal heat at end of H.-P. stroke . . . I_2	1,035·30	799·70	496·23	1,059·03	1,047·80	1,134·60	264·93	315·77	583·70	..
Internal heat shut in H.-P. cylinder by compression . . . . . $I\,c_1$	12·88	19·27	15·21	87·02	87·02	80·75	37·07	44·53	63·54	..
	1,022·42	780·43	481·02	972·01	960·78	1,053·85	227·86	271·24	520·16	..
Work of expulsion from H.-P. cylinder in thermal units . . . . . W e	21·56	20·33	15·58	25·44	26·37	24·30	9·89	12·08	31·47	..
Indicated work in H.-P. cylinder	148·80	53·47	43·30	83·39	82·98	91·06	20·15	23·91	53·49	..
Radiation from H.-P. cylinder . . . . R_H	15·00	6·90	6·90	7·00	7·00	7·00	1·30	1·60	7·00	..
Heat given up by condensation in L.-P. and receiver jackets . . . . . $M_J L_1 + M_J L_R$	..	..	30·80	45·23	49·32	..	..	..	47·66	..
Exhaust waste from H.-P. cylinder . . . Q e	286·02	244·12	71·60	249·37	211·98	291·41	58·75	67·99	113·13	..
Total heat through engine . . . . . Q	1,493·80	1,105·25	649·20	1,382·44	1,338·43	1,467·62	317·95	376·82	772·91	..
	BY FORMULA 3.									
Heat given up to walls of H.-P. cylinder during admission . . . . . Q a	488·76	404·97	191·26	356·13	333·58	362·75	104·95	127·22	147·89	..
Heat given up during compression . . . Q d	− 0·64	1·76	− 7·13	35·35	43·57	28·24	11·80	13·04	37·32	..
Heat given up by condensation in H.-P. jacket M L_R	49·60	..	21·00	30·00	33·00	..	..	..	32·43	..
Total heat given up to walls of H.-P. cylinder. .	537·72	406·73	205·13	421·48	410·15	390·99	116·75	140·26	217·64	..
Heat absorbed by steam during expansion in H.-P. cylinder + radiation . . . . . Q b + R_H	251·70	162·61	133·53	172·11	198·17	99·58	58·00	72·27	104·51	..
Exhaust waste . . . . . Q c	286·02	244·12	71·60	249·37	211·98	291·41	58·75	67·99	113·13	..
Total heat given up from walls of H.-P. cylinder .	537·72	406·73	205·13	421·48	410·15	390·99	116·75	140·26	217·64	..

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TABLE X.—EXHAUST WASTE FROM LOW-PRESSURE CYLINDER. BY DIRECT MEASUREMENT (FORMULA 10).

——	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.
Internal heat at end of low-pressure stroke . . I_3	..	787·30	539·87	1,036·67	1,026·33	953·67	244·29	287·19	546·82	..
„ „ of steam shut in low-pressure cylinder by compression . . . . . $I\,c_3$	..	26·44	21·93	9·05	8·44	13·88	20·86	20·86	10·60	..
	..	710·86	517·94	1,027·62	1,017·89	937·79	223·43	266·33	536·22	..
Work of expulsion from low-pressure cylinder in thermal units . . . . . $W\,e_1$	..	16·90	12·18	10·84	9·88	13·34	8·64	9·47	12·03	..
Indicated HP. + radiation in thermal units $W\,i + R$	..	107·86	98·80	186·73	184·35	182·88	35·16	43·27	136·27	..
Exhaust waste . . . . . $R\,c$	..	269·63	20·28	157·25	126·31	331·61	50·72	57·75	88·39	..
Total heat through engine per stroke . . . . Q	..	1,105·25	649·2	1,382·44	1,338·43	1,467,62	317·95	376·82	772·91	..
					BY FORMULA 4.					
Heat given up from walls of high-pressure cylinder during supply to low-pressure . . . . . $Q\,c$	..	244·12	71·60	249·37	211·98	291·41	58·75	67·99	116·83[1]	..
Heat given up by compression . . . . . $Q\,d_1$	..	−3·92	−7·46	−2·74	−1·49	−3·32	−0·73	−0·56	−6·69	..
„ „ condensation in low-pressure jacket $M_1\,L_1$	..	..	30·80	45·23	49·32	..	..	..	37·24	..
Total heat given up to walls of low-pressure cylinder .	..	240·20	94·94	291·86	259·81	288·09	58·02	67·43	147·38	..
Heat absorbed by steam during low-pressure stroke + radiation . . . . . $Q\,b_1 + R_1$	..	−29·43	74·66	134·61	133·50	−43·52	7·30	9·68	58·99	..
Loss through cooling action of condenser . . . $R\,c$	..	269·63	20·28	157·25	126·31	331·61	50·72	57·75	88·39	..
Total heat given up from walls of low-pressure cylinder	..	240·20	94·94	291·86	259·81	288·09	58·02	67·43	147·38	..

[1] The heat given up by condensation in the receiver jacket has been added to, and the external radiation deducted from, Q c as found in Table IX.

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TABLE XL.—CONSUMPTION of COAL PER INDICATED HP. PER HOUR.

——	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.
Total heat through engine per stroke ($Q - Q_1$) calculated from the temperature of the air-pump discharge	1,445·20	1,037·98	621·40	1,360·39	1,314·54	1,441·00	299·44	351·91	747·75	5,094·53
Thermal units per Indicated HP. per minute calculated from the temperature of the air-pump discharge	415·10	487·90	324·2	342·6	335·7	371·3	400·5	383·1	281·5	448·0
Lbs. of coal per indicated HP. per hour, supposing feed-water, taken from hot well and coal, to give up 11,000 thermal units per lb.	lbs. 2·26	lbs. 2·66	lb. 1·76	lb. 1·86	lb. 1·83	lbs. 2·02	lbs. 2·18	lbs. 2·09	lb. 1·53	lbs. 2·44
DISPOSAL of HEAT ($Q - Q_1$) PASSING THROUGH ENGINE PER STROKE.										
Indicated work per cent. . .	10·3	8·7	13·2	12·5	12·7	11·5	10·7	11·1	15·2	9·5
Rejected heat and error per cent.	88·7	89·7	84·1	86·3	86·0	87·3	88·2	87·8	81·8	89·6
Radiation per cent.	1·0	1·6	2·7	1·2	1·3	1·2	1·1	1·1	3·0	0·9

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TABLE XII.—SUMMARY OF RESULTS.

——	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.
Absolute boiler pressure in lbs. per square inch	48	58	62	84·8	88·14	88·95	86·05	84·77	76	46·4
Revolutions per minute	14·62	17·84	19·62	33·73	34·22	34·52	80·45	81·51	23·98	(Strokes) 12·84
Speed of piston per minute in feet	160·82	196·24	215·82	371·03	376·42	379·72	683·82	692·83	263·78	201·33
Total number of expansions	6·85	9·3	15·76	9·64	9·56	7·77	11·48	11·64	13·61	..
Type of engine	Single Cylinder.	Woolf Beam.		Woolf Beam.			Woolf Tandem.		Receiver.	Cornish.
Percentage of supply from boiler passed through jacket	4·0	Jacket not in use	9·9	7·1	8·3	Jacket not in use	No jackets on cylinders		13·2	4·5
Indicated HP.	101·79	75·9	75·2	267·86	267·95	267·92	120·30	149·75	127·40	146·02
Total HP.	115·04	87·36	85·09	284·25	282·55	288·69	147·39	177·32	138·30	183·62
Percentage of loss through back pressure	11·5	13·1	11·6	5·8	5·1	7·0	18·3	15·5	7·9	20·4
„ water present in cylinder at cut-off	43·8	51·1	40·8	37·6	37·7	34·0	42·6	43·6	34·1	..
„ „ „ „ end of high-pressure stroke	28·4	35·1	18·1	24·3	21·5	28·0	25·4	25·5	22·3	..
Percentage of water present in cylinder at end of low-pressure stroke	..	38·8	8·7	17·5	14·3	35·2	26·3	26·3	19·9	..
Percentage of total heat through engine lost by R c	19·1	24·4	3·1	11·3	9·4	22·5	15·9	15·3	11·4	..
Thermal units per indicated HP. per minute	429·11	519·5	338·8	348·1	341·8	378·1	425·2	410·2	291·0	469·5
„ „ „ total HP. per minute	379·8	451·4	299·3	328·1	324·2	350·9	347·09	346·4	268·0	373·4
Pounds of dry saturated steam per indicated HP. per hour	22·06	26·62	17·34	17·73	17·39	19·24	21·65	20·88	14·84	24·15
Pounds of dry saturated steam per total HP. per hour	19·52	23·13	15·32	16·7	16·49	17·85	17·66	I7·64	13·67	19·21
Maximum theoretical efficiency[1]	0·281	0·254	0·276	0·340	0·339	0·341	0·281	0·268	0·305	0·257
Actual efficiency[2]	0·099	0·082	0·126	0·122	0·125	0·113	0·1005	0·104	0·147	0·091
Thermal units absorbed by injection water per indicated HP. per minute	..	440·9	265·6	..	..	..	342·8	321·0	219·8	392·7
Donkin's coefficient	..	454·6	272·5	..	..	..	359·7	340·4	225·1	406·9

[1] Obtained from the formula $\frac{T_1 - T_2}{T_1}$ in absolute degrees of temperature.

[2] Actual efficiency $= \frac{33,000}{772} \div$ T U per IHP.

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(*Paper No. 1861.*)

"Buckie Harbour."

By JAMES BARRON, Assoc. M. Inst. C.E.

BUCKIE is situated on the south side of the Moray Firth, about midway between the towns of Portsoy and Lossiemouth. It has a population of upwards of six thousand inhabitants, who are mostly fishermen, and the surrounding country is a rich agricultural district.

There are six hundred fishing boats belonging to the district, representing a capital of £120,000. In 1854 the fishermen, along with the proprietor of Nether Buckie, Sir Robert G. Gordon, Bart., applied to the Board of Fisheries for a grant to build a harbour, and they obtained the sum of £13,000. This sum was supplemented by the proprietor to the extent of £4,500, and a harbour was designed by Messrs. D. and T. Stevenson, MM. Inst. C.E., the engineers to the Board of Fisheries, and was constructed about 1 mile to the west of the harbour about to be described. It was, however, inadequate for the accommodation of so many boats, and was comparatively useless as a harbour of refuge during storms, while it was wholly dry at low water of ordinary spring tides.

The subject of increased harbour accommodation was from time to time agitated by those interested in the fishing industry, and in consequence of a memorial addressed to the Board of Fisheries by the Commissioners of the County of Banff after the great loss of life during the gale of the 23rd of November, 1857, Messrs. D. and T. Stevenson were instructed by the Board of Fisheries to report as to the most suitable place for a low-water boat harbour of refuge on the coast of Banffshire.

After examining various sites and hearing the evidence of local fishermen and others, the Messrs. Stevenson reported that "the most certain and the most safe investment of public money, as well as the most economical method of supplying the wants of the coast, is to construct the works we have recommended at Craigenroan."

Nothing was done in the matter until 1864, when another gale occasioned the loss of twenty-six persons. After that the matter was taken up by the late Mr. John Gordon of Cluny, proprietor of Buckie, who happened to be an eye-witness of the wrecks of the

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fishing-boats and loss of life in the gale of 1857, and he requested the Messrs. Stevenson to report on the capabilities of "Salter's Bay" for a refuge boat harbour. In their report they stated that "a good harbour for supplying the ordinary wants of the numerous fishermen of Buckie could be erected at 'Salter's Bay.' This same site had been selected by the late Mr. Telford in 1805.

In 1873 Mr. Gordon requested Mr. Dyce Cay, M. Inst. C.E., to report to him on the formation of a fishing harbour at Buckie. Mr. Cay thereupon proposed a scheme for the formation of a harbour in "Salter's Bay," and subsequently, as instructed by Mr. Gordon, prepared Parliamentary plans and estimates of the scheme for which the Board of Trade provisional order was granted in 1874. The works have been carried out on the basis of this scheme, with modifications in the direction of giving increased depth of water and accommodation.

Site and Form of Harbour.

The exact site selected had frequently been used by fishing craft as a safe place to shelter during storms, as there was a long ridge of rocks running seaward in a north-westerly direction forming a natural breakwater; this ridge was subsequently utilized for the foundation of the sea-wall and breakwater. The harbour consists of two basins, an inner and an outer one, which together cover an area of 8 acres.

Order of Execution of Works.

The necessary temporary buildings were first erected, namely:—

	Feet.	Feet.
(1) Cement, stone and testing room	100	by 22
(2) Blacksmith's shop with two forges	30	,, 20
(3) Carpenter's shop	20	,, 20
(4) Store	36	,, 16
(5) Dynamite magazine	8	,, 8
(6) Workmen's bothy	16	,, 16
(7) Engineer's office	16	,, 16

All the above buildings were built of timber and covered with roofing felt; the floors were of cement store, the workmen's bothy and engineer's office were floored with Portland cement concrete.

After the preliminary works, including the erection of the mixing machinery, had been executed, the first thing done was to erect the sea wall of the east pier, and the west wall of the middle

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pier, with the object of enclosing the whole area of the inner harbour, so that the foundations of the walls round the same, and also the area of the harbour, might be excavated dry. The outer or west wall of the middle pier was founded with a cofferdam 4 feet below low-water level, and the inner wall of the east pier was founded with cofferdams 7 feet below low-water level. To economise labour in such tidal work, and to expedite the progress of construction, it was found advisable to build this wall on piers 4 feet thick, placed so that the clear span of the arches was 20 feet. This plan saved a considerable amount of rock excavation, and the recesses helped to break the strength of the waves after they entered the harbour. When these two walls had been erected the proposed entrance to the inner harbour was closed with a temporary concrete wall having four sluices built into its base at low-water level, the whole forming a secure and convenient cofferdam.

The water was completely shut out from the inner harbour in June 1877. Thereafter the work of excavation proceeded smoothly and rapidly. A 6-inch centrifugal pump driven by a 12-HP. portable steam engine, working sixteen hours per day, sufficed to keep the water under. It sometimes happened when a heavy storm came on, that, as a prudential measure, the water was admitted to the area, and tools, &c., were temporarily removed. Upon one occasion, however, before this could be accomplished, the waves rose over the outer wall of the middle pier, and collected to so great an extent behind the inner one which had just been erected, that the concrete, still green, could not resist the pressure, and a short length of the wall gave way; this was the only accident which occurred during the execution of the works. Thirteen months from the date upon which the water was shut out it was re-admitted, the whole excavation having been completed.

Simultaneously with the work of excavation the breakwater and west pier were proceeded with, and completed by July 1878 with the exception of a short length of the west pier, which was left unbuilt until the rock in the entrance channel had been blasted.

The Diamond Rock Boring Company of London entered into a contract for the blasting of the rock in the entrance channel, which was all below low-water level. The company undertook to blast 5,250 cubic yards for the sum of £3,300; they commenced operations in 1877, and at the end of 1879 had blasted about half the contract quantity. They ultimately agreed to give up the work, which was then undertaken as part of the general works by the Author. During the first three summer months of 1880 this

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work was accomplished, and the blasted rock was dredged and the channel completed by October 1880. The remaining portions of the west pier and parapets were carried out subsequently, and the harbour was opened for use in November 1880. The only things remaining to be done were the making of roads, laying out yards for traders, establishing fishing stations and stores, and the erection of a beacon on a reef of rocks about ½ mile from the harbour entrance, the whole of which has now been completed.

Materials.

The works have been built *in situ* with Portland cement concrete made of various proportions, depending upon its exposure to the sea, or liability to wear by vessels or traffic, these proportions varying from 4 to 12 parts of sand and rock to 1 part of cement. The whole of the cement used, amounting to 7,000 tons, was supplied by the Barham Cement Company at an average cost of £2 3*s.* 6*d.* per ton, delivered free at Buckie.

The following are extracts from the specification for the cement; but the tensile strength in every case exceeded the requirements of the specification:—"The cement is to be finely ground, and when sifted through a gauze sieve having nine hundred holes to the square inch, at least 95 per cent. by weight of the cement is to pass through without rubbing. It is to weigh not less than 115 lbs., and not more than 122 lbs. per striked bushel, imperial measure, the bushel being filled from a spout or hopper 18 inches above the mouth of the bushel. Sample blocks are to be made of the cement in a metal mould having a maximum area of 2¼ square inches; these blocks are to be immersed in water immediately after setting sufficiently to allow of their being taken out of the mould, and are to remain in the water until tested; at the expiry of seven days after gauging, they are to be tested by tensile strain, and are to bear without breaking a strain of 675 lbs. per block. The cement at the time of delivery is to be in all respects ready for use, and there are to be no cracks or symptoms of 'blowing,' or heat in the sample blocks."

Sand and stones were found in abundance near the site of the works, and a considerable quantity of rock, excavated from the inner harbour, was incorporated in the concrete building. The materials excavated from the inner harbour were used for the hearting or the filling of piers.

The water for the manufacture of the concrete and for other purposes was forced from a stream ¼ mile from the works, by a

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hydraulic ram over a cliff 60 feet high into a tank 25 feet long by 14 feet wide and 3 feet deep, made of timber planking 3 inches thick, and was distributed over the works in lead pipes.

Manufacture of the Concrete.

The materials, sand and stones, were conveyed by ordinary ballast-wagons to a site near the mixing machinery, and were afterwards carefully measured in wheel-barrows, which contained 2¼ cubic feet. The proper quantity or charge for the mixers, including cement, was then put into small wagons, and drawn up an incline to hoppers, placed over the mixers. Two of Messent's mixers were used, and were wrought by an 8-HP. engine, which also drew the wagons, containing the materials as measured for mixing, up to the hoppers. The sand, stones, and cement, were then dropped from the hopper into the mixers, and a proper quantity of fresh water, drawn from a wooden tank, with a gauge placed close to the mixers, was added, and after twelve revolutions of the mixer its contents were dropped into wagons beneath, and conveyed to the various parts of the works where required. It was found that the mixers could best mix 15 cubic feet of concrete at one time, and the two mixers could mix 38 cubic yards per hour.

The number of men required to work the mixers and machinery, exclusive of those employed measuring and wheeling the raw materials, was seven, namely, one engine-driver, two men attending the hoppers on the upper platform, two men at the mixers, one man emptying the mixers into the wagons, and one at the water-supply. The number of men required to measure and supply the raw materials varied, as the distance between the ballast platform and heap was continually changing.

Framing, Moulds, and Depositing of Concrete Work.

The form of the walls was determined by timber framework and planking, made and erected to suit the various sections of the walls. The framing for the south quay wall, which was partly built against rock, was kept in position by temporary shores, 9 inches square in cross section, and lined with planking 2½ inches thick. The upper part of this wall required timber on both sides, which was secured with ¾-inch wrought-iron tie-rods, with washer and nut on each end. The tie-rods were, previous to the concrete being filled in, protected by ∧ shaped covers, made of two pieces of timber. This arrangement allowed the tie-rods to be drawn

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out for further use after the concrete was consolidated. The framing for the breakwater, and part of the west pier, the former founded at a depth of 10 feet, and the latter at a depth of 7 feet, below low-water mark of ordinary spring tides, was erected in the following manner:—Horizontal beams of timber, 9 inches square, were bolted to posts of the framing of the last piece of concrete built. These beams projected in line of the extension of the wall. Posts, 9 inches square in cross section, were then erected 6 feet apart from centre to centre, and bolted to the horizontal beams, and lined on the inner side with planking 2½ inches thick. The planking beneath low-water mark was fixed by helmet divers, and ¾-inch wrought-iron tie-rods were used for keeping the framework in position. To secure the framing from being washed down by the sea, it was found necessary to load it with old rails, until such time as a portion of the concrete was deposited. Notwithstanding these precautions, the timber framing was on several occasions washed down by the sea. The concrete used under low-water mark was made in the proportion of 4 parts of sand or rock to 1 part of cement. Into the casing of timber, as above described, a bag of ample dimensions, made of several thicknesses of jute cloth, weighing 19½ ounces per square yard, was drawn down into position by ropes and pulleys secured to the lowest tier of planking. The concrete was then tipped from ordinary ballast wagons, through from 7 to 10 feet of water. When thus deposited, the concrete spread equally over the whole area of the mould or piece which was being built, and the jute cloth protected the concrete from the wash of the sea until it was consolidated. The moulds or framework for the parapets, tunnel, and lighthouse, were made in panels of suitable lengths, shifted and erected with a 4-ton portable steam crane, which also deposited the concrete when brought from the mixers in wooden skips on bogie wagons.

The following were the proportions of concrete in the breakwater and west pier above low-water level:—In the sea face and harbour face, for a thickness of 5 feet, 7½ parts of sand or stone to 1 of cement, hearting 12 parts of the former to 1 of the latter, while a considerable number of large clean stones were incorporated in the concrete in addition. The concrete in the parapets, lighthouse, and harbour face, of the east quay, including arches and piers, was made in the proportion of 5 parts of stone to 1 part of cement. All the timber-casing was lined on the inside up to high-water level with jute cloth, weighing 17 oz. per square yard, secured with 1-inch clout tacks.

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Excavation and Blasting.

The greater portion of the materials to be excavated consisted of sandstone rock mixed with quartz. At the commencement of the excavation the rock-boring was for some time done by hand-drills, and ordinary blasting-powder was used; but as soon as the water had been excluded from the inner harbour, two Ingersoll steam-drills were introduced, one drill with a 3¼-inch cylinder, and the other with a 2¾-inch cylinder. The steam was supplied at a pressure of 50 lbs. per square inch by a 5-HP. Davey-Paxman boiler. With reference to the relative cost of hand- and steam-boring, a number of experiments were made at a time when it was found necessary to employ both hand- and steam-drills simultaneously. The two following Tables, selected from twelve Tables of experiments, represent the average results from both systems.

Table I. Hand-Drilling.—Each boring required three men, at 4*d.* per hour, namely, two strikers, and one man at the drill. The time occupied in the shift is included:—

No. of Holes Drilled.	Total Depth Bored.	Time occupied.	Time required to drill 1 lineal foot.	Cost for Labour per lineal foot.	Diameter of Drill.	Cost per Hour.
	Feet.	Hours.	Minutes.	*d.*	Inch.	*d.*
72	388	216	33·4	6·68	1·5	12·00

Table II. Steam-Drilling.—Two Ingersoll drills required per hour one fireman at 4·5*d.*, and three men at 4*d.*, making the working cost for one drill, allowing 6*d.* per hour for fuel, 11·25*d.* per hour.

No. of Holes Drilled.	Total Depth Drilled.	Time occupied.	Time required to drill 1 lineal foot.	Cost for Labour per lineal foot.	Diameter of Drill.	Cost per Hour.
	Feet.	Hours.	Minutes.	*d.*	Inch.	*d.*
88	498	124·5	15·0	3·25	1·5	11·25

From the above results, which are approximate, it will be seen that the average cost by steam-drilling was 50 per cent. less than by hand-drilling.

The total quantity of rock excavated was 110,000 cubic yards, of which the greater portion was loaded into ordinary ballast wagons, and drawn up an inclined wagon-road by a winding engine. The material was placed on the level of the quays, and

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deposited on the east side of the harbour to form an embankment, which is now used for harbour purposes.

The explosive employed was Nobel's No. 1 dynamite, and the total quantity used was 4 tons. It was fired by Bickford Smith and Company's gutta-percha No. 14 fuse and treble detonators. No accident occurred with the dynamite. The following rules were posted in the room where the charges were prepared:—

ROCK BLASTING.

Rules to be observed by Firemen.

"I. The fireman or blaster is to have the sole charge of the magazine, and no other person is to be allowed to enter the magazine on any pretence whatever.

"II. Should the dynamite become frozen or hard, it must be thawed or softened in the warming-pan only.

"III. The dynamite must not in any instance be placed near a fire or steam-pipe, and it is to be thawed or softened only in the way above directed.

"IV. No more dynamite to be taken from the magazine to the works than the exact quantity required; and in the event of any being left over, after charging the bores to be fired, it is to be immediately removed to the magazine.

"V. The detonators and fuses to be kept quite separate from the dynamite.

"VI. In case of a missfire the spot is not to be approached until ample time elapses for the fuse to be burnt down. In the event of a bore which has been charged being left unfired, the spot is to be carefully marked to prevent reboring in too close proximity to the unfired bore, and the fireman will be responsible that no person is in dangerous proximity to the point of blasting when he fires the shot.

"VII. Before a shot is fired, a horn is to be sounded, and two men are to be told off, one in each direction, along the road near the works, to stop and warn any person who may be too near the site of the blast.

"VIII. All the bores above L. W. M. are to be fagged with chains and brushwood.

Blasting under L. W. M.

"I. The diver will instruct the fireman in regard to the shape and dimensions of the charge of dynamite. On no account is the magnetic exploder to be connected to the wires until the divers

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are in their boat, which must be a sufficient distance from the site of blast."

The submarine boring and blasting in the entrance channel was executed in the following manner:—A light timber platform of loose deals was set on wrought-iron bearers, which acted as braces to upright tripods, made of old service rails. The tripods were easily shifted by barge-crane as the work progressed, while the platform was used until the tide rose and floated it off the bearers, when it was towed ashore.

The exact position for each bore-hole was fixed by helmet divers, who cleared away any sand or loose materials which lay on the surface of the rock, and then set a heavy cast-iron guide, with an opening for the drill. In some cases it was found necessary to place stiff clay round the base of the guide to prevent fine sand from running into the bore-hole. Nine sets of borers were at work at one time. Each set consisted of three men; the drills varied in length from 12 to 20 feet, and their diameter was 1½ inch. The charges of dynamite, made up in tin canisters, were placed in the hole by divers, and were fired by a magnetic exploder.

When the whole of the rock in the entrance channel had been blasted, a steam dredger and barges were hired to lift the materials; this took three months. During the progress of dredging it was found that a considerable portion of the rock which was bored and blasted by the Diamond Rock Boring Company required to be re-bored and blasted, otherwise the dredging would not have taken so long a time. The materials dredged were lifted off barges by a steam crane, and were converted into road metal.

Lighthouses and Beacon.

The position of the harbour is indicated by a 6th order dioptric light, which was supplied by Messrs. Chance Brothers, of Birmingham. The light is placed in a cast-iron lamp, on the top of a concrete tower at the end of the breakwater, at an elevation of 55 feet above high-water level. It is white, and is seen between E. ½ N. and W. ½ S., and is visible for a distance of 12 miles. A tunnel is formed in the parapet of the breakwater for safe access to the lighthouse in stormy weather.

There is also another light, a 10-inch holophotal lens and silver-plated mirror, in a cast-iron tower, set on a base of concrete on high ground south from the harbour, and in line of the entrance, at an elevation of 80 feet above high-water level. Its object is to

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guide vessels in entering the harbour at night, and also in avoiding a ridge of rocks which lie about ½ mile seawards of the harbour. This ridge of rock is visible at low water, and its west end is indicated by a tower built of concrete, rising 10 feet above high-water level.

The two lighthouses, quays, and piers, are lighted by gas from the town. The supply-pipes are of galvanised iron, and the pipes which convey the gas along the west pier and breakwater are placed on parapets in such a position as to form a convenient hand-rail. Protecting chains of galvanised iron are hung on portable standards on the quays along the south side of the harbour.

Cost of the Works.

The following is an approximate statement showing the quantities and the cost of some of the principal items:—

(1) *Temporary Buildings.*

	£.
Cement store	250
Blacksmiths' shop	50
Carpenters' „	40
Store	30
Dynamite magazine	25
Workmens' bothy	30
Engineers' office	35
	460

These buildings are now partly occupied as business premises by various parties, from which an annual revenue of £32 is realised.

(2) *Plant.*

	£.
Steam boring machinery	377
Mixing machinery and staging	758
Pumping „ „	400
Diving apparatus	150
Boats and barges	300
Service rails	400
Wagons, barrows and carts	480
Blacksmiths' tools	32
Chains, ropes and blocks	80
Cement—testing apparatus	49
Cranes	468
Sundry plant	100
Hydraulic ram and pipes	80
Stable fittings and harness	40
Timber	500
	4,214

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Cranes, barges, and diving apparatus, &c., to the value of £1,000 now form part of the permanent working plant of the harbour, for which dues are leviable under the Provisional Order. The remaining portions of the plant when sold will possibly realise the sum of £2,400, being equal to a reduction of 25 per cent. on their prime cost, or a total cost chargeable against the works for plant of £800.

(3.) The cost of the Portland cement concrete, under low-water mark (18,000 cubic yards), was 20*s.* per cubic yard; above low-water mark (30,000 cubic yards), 15*s.* per cubic yard.

(4.) The cost of rock blasting and dredging in the entrance channel (5,250 cubic yards) was 20*s.* per cubic yard.

(5.) The cost of the coffer-dam for the inner harbour was £300.

(6.) The cost of excavation (110,000 cubic yards) was 2*s.* per cubic yard.

The total cost of the works, including the making of roads, erecting stores for traders, and laying out the ground, &c., was £60,000, and the whole expense has been borne by the late Mr. John Gordon, of Cluny, and subsequently by his trustees, as administered by Mr. Ranald Macdonald, Estates Commissioner.

Since the completion of the harbour two railway companies, namely, the Great North of Scotland Railway, and the Highland Railway, have this session obtained Parliamentary sanction for the construction of lines of railway to Buckie from the centres of commerce, and a steamer trading between Liverpool, Leith, Aberdeen, Buckie, and Inverness, calls twice a week.

A model of the harbour was exhibited at the International Fisheries Exhibition, Edinburgh, for which a silver medal was awarded.

The works were executed without a contractor, from designs by Mr. David Cunningham, M. Inst. C.E., and were carried out under his directions, the Author being the Resident Engineer.

The Paper is accompanied by a drawing, showing sections of the piers, &c., and a general plan of the works, from which Plate 12 has been prepared.

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(*Paper No. 1865.*)

"Bo'ness Harbour and Dock Works."

By PATRICK WALTER MEIK, M. Inst. C.E.

BORROWSTOUNNESS, or, as it is generally called, "Bo'ness," is a town of five thousand inhabitants, on the south shore of the Firth of Forth, about 8 miles above Queensferry and 16 miles above Leith (Plate 13, Fig. 1). About one hundred and fifty years ago it was the second port in Scotland, but the trade gradually declined until just before the introduction of railways, at which time it was, commercially, almost dead. However, one of the first railways made in Scotland was the Slamannan line, which connects the Airdrie and Slamannan coal district with the Firth of Forth at Bo'ness; and the construction of this line, with the chief object of getting the coal to the sea for shipment, had the effect of giving a new impetus to the trade of the place. The Kinneil Ironworks, in the immediate neighbourhood, also aided by their traffic to maintain the little harbour in life. But the increase in the size of vessels, and the introduction of steam, contributed to render the accommodation of the port—which was, no doubt, well enough suited to the trade of half a century ago—inadequate to meet the wants of the present day.

In 1874, the town authorities, to whom the harbour belonged, recognised the necessity for harbour-extension, and the Author's firm was authorised to prepare the necessary plans, &c. The designs then submitted involved the extension of the piers seaward for a distance of about 800 feet, and the construction of a dock of 4 acres, on a site to be reclaimed from the sea. The depth of water on the sill was proposed to be 20 feet at high water of ordinary spring tides, and the expenditure was estimated at £185,000, of which the piers were to cost £75,000, and the dock and reclamation works £110,000. The trustees resolved to carry out the whole of these works as quickly as funds could be raised for the purpose; accordingly a start was made with the piers, part of which, at any rate, would require to be finished before the dock-works could be proceeded with.

A general plan of the works as they have been carried out is shown in Plate 13, Fig. 2. It will be seen that part of what was the new east pier was a cofferdam widened and strengthened to

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serve as a pier and quay until the dock-works were completed. The construction of this dam, 300 feet in length, about 280 feet of the permanent portion of the east pier, and 350 feet of the west pier, occupied the three years 1876–78, the funds being obtained from the Public Works Loan Commissioners and other sources. During this period the town authorities were busy negotiating for the much larger sum required to construct the reclamation and dock-works.

In 1877 an agreement was made with the North British Railway Company by which the town and the railway were to share the management, and the Company was to advance the additional capital required. The size of the dock was, however, increased from 4 to 7½ acres, and the depth of water on the sill fron 20 to 22 feet at spring tides, raising the estimate for the dock and reclamation works alone to £180,000, and the total to £255,000.

The contract for the dock was let in June 1878 to Mr. T. S. Hunter, of Glasgow, and a start was made in September of the same year, the time of completion being fixed as the 1st of January, 1882.

Borings were taken over the whole site of the works, principally with the view of choosing the most favourable site for the dock entrance. It was known that the shores of the Firth in the neighbourhood were composed of silt, mud, and soft clay, extending to a great depth, and there was little prospect of finding any other foundation. As the character of the deposit varied considerably, it was highly desirable to have as sound a foundation as possible for the most important parts of the work. The borings in some places showed silt to about 60 or 70 feet below low-water level, and on one occasion did not get through the mud even at this depth; but in other places, principally near the shore, there was found a fine red clay, destitute of stones or coarse particles, perfectly water-tight, and of a consistency something like butter. The entrance and the whole of the dock walls have been founded on this material; the walls of the entrance-basin and the piers being, however, on the silt or on fine dirty sand.

A section of the west pier is shown on Plate 13, Fig. 3. The main front piles are of greenheart, and the remainder of the timber of creosoted memel or pitch pine. The main piles are 52 feet in length, the sheet piles 30 feet, and they are driven to 28 feet below low-water. The material forming the body of the pier consists of slag from the Kinneil Ironworks, which are about 1 mile from the harbour. The west side was faced with a rough wall of blocks of slag, protected by timber, sufficient to form a quay, alongside which

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small vessels can lie; on the harbour-quay a 25-ton steam crane was erected for coal-shipping. The whole of the hearting of this pier, and the blocks of slag on the west side, have sunk considerably, but without disturbing the line or levels of the timberwork on the harbour side. The total cost was £34 14*s.* per lineal foot.

The east pier-cofferdam, Plate 13, Fig. 4, having, as already explained, to serve the double purpose of a cofferdam and a pier or quay, was made of a substantial character. The main piles are 53 feet in length, the sheet piles 30 feet, and driven to 26 feet below low-water, or 3½ feet below the lowest part of the sill. While the foundations of the entrance were being put in this dam moved a little, but the movement, never very serious, ceased when the outer portion of the entrance foundations had been completed. The cost of this pier-cofferdam was £16 8*s.* per lineal foot.

Owing to the form of the basin, the section of the east pier varies considerably. That shown in Plate 13, Fig. 5, is an average through the curve. When the pier-works were being constructed the level of the mud in the harbour was from 4 to 6 feet above low-water, and as it was necessary to carry the foundation of the concrete wall of the pier down to the future bottom of the channel, 6 feet below low-water, there was a layer of from 10 to 12 feet of mud to excavate by tide-work. In order to render this practicable the concrete wall was enclosed in sheet-piles back and front, the piles being carried up to near the top of the mud; every second pair of piles was tied together by tie-rods 1 inch in diameter, which were left in the concrete. The whole of the concrete of this pier has sunk from 3 to 6 inches since its completion, but without the concrete cracking. The cost of this work was £45 per lineal foot.

The cofferdams, to enclose the space required for the dock, were at first intended to commence at the east pier, running eastwards round the outside of the land to be reclaimed; but the line was altered to the position shown in the plan in order to avoid some particularly soft and treacherous ground revealed by the boring at X, Plate 13, Fig. 2. At this boring the rods on more than one occasion sank several feet at a time, and were nearly lost. The clay was at a moderate depth at the site fixed for the entrance, but it dipped rapidly towards the north or north-west, and it was thought by the engineers that although a dam on the site of the west barrier would be about 350 feet from the entrance, a movement was likely to take place during the excavation for the sill which might be disastrous. The site chosen for the main dam, although only 170 feet from the entrance, was on much better ground; and in order to give extra security the west barrier was constructed,

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and part of the triangular space at X filled in, before much work had been done at the entrance. The result was highly satisfactory, as no appreciable movement took place in dam No. 1. It is shown in section in Plate 13, Fig. 6; the main piles are 57 feet in length, and of a scantling 14 inches square. There is one row of sheet-piles 35 feet in length, and of a scantling 12 inches by 8 inches, driven till their heads are 3 or 4 feet above low-water; above the sheet-piling the clay is contained between 3-inch planks. To add stability, the dams being exposed to the sea, whinstone rubble was deposited on the sea-face, and the dams were backed with burnt shale or "blaize" from pit heaps in the neighbourhood. The total cost was £12 15*s.* per lineal foot.

It being desired to utilise a portion of the dam as a permanent quay for barges and small river craft, a different section was adopted for a length of 500 feet of the reclamation barrier. It is shown in Plate 13, Fig. 7, and is a timber wharf with a light concrete wall at the face. This wall served for the exclusion of the water during the construction of the dock, as well as a quay for landing ballast and other materials. Its cost was £19 14*s.* per lineal foot.

The remainder of the reclamation wall, stretching eastward from the concrete barrier, was of a similar section to that shown in Plate 13, Fig. 6, but gradually decreasing in strength, until at the shore end a single row of piles and planking backed with clay was considered sufficient. The dams, which were altogether 2,630 feet in length, proved watertight, and occasional pumping was sufficient to keep the works dry.

The whole of the dock-walls and entrance except the sills, quoins and coping were constructed of concrete. The cement bore a tensile strain of 1,000 lbs. on 2¼-inches section. It was stipulated to leave only 10 per cent. residue when passed through a 50 wire-gauge sieve; and although none of it absolutely complied with this latter stipulation, yet a satisfactory degree of fineness was maintained throughout. There being no materials near the works, such as ballast, sand, or stone for making concrete, the question of expense entered largely into the consideration of the materials to be used. In the earlier parts of the work, such as the east pier and the crane foundation on the west pier, slag from the Kinneil iron furnaces was mixed with ships' ballast. This slag, however, cannot be regarded as a good material for the purpose. It is much more friable than Cleveland slag, and of small specific gravity; indeed the Author has seen lumps 1 foot in diameter floating away with the tide. It is also very porous, and from the

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large amount of cement absorbed, it is doubtful if there was much saving in its use.

Before the dock walls and entrance were commenced, it was decided to abandon the use of slag, and a series of experiments were made to determine the relative value of two other materials which could be obtained at comparatively moderate cost. These were broken whinstone from Carlinnose quarries, Queensferry, 8 miles down the Firth, and the burnt shale or blaize already referred to, from the neighbouring pit heaps. The shale has been burnt till it is red throughout, except in the case of very large lumps, and it possesses a high specific gravity, being nearly as heavy as sandstone. In appearance nothing could look more satisfactory than concrete made from the blaize, and this material could be obtained at about half the cost of whinstone.

The tests were of two kinds; first, a number of blocks were made 6 inches and 9 inches cube, and were broken in a hydraulic press; and secondly, a series of arches and beams were broken by direct weight. The pressure applied was measured by a hydraulic pressure-gauge, and in the other cases the weights were ascertained by beam and scale.

The results of the tests are given in Appendix I.; these are in favour of the concrete made with the burnt shale in the younger blocks, but slightly in favour of the whinstone after the blocks had been made ten months. This result appeared to be due to the fact that the shale was more porous than the whinstone, and that the concrete in consequence set more quickly. It was noticed that all the whin concrete broken in the first series of tests was damp in the centre of the block, while the blaize concrete was dry through; in the latter series, however, both appeared thoroughly dry.

In constructing works of concrete when the surrounding material is retentive of moisture, and where it is necessary or advisable to subject the walls to pressure at a comparatively early date, the time taken by the concrete in setting becomes a matter of great importance. This was undoubtedly the case at Bo'ness, where it was necessary to back up the walls quickly, and where the material adjacent to the lower part of the wall was highly charged with water. It seemed to the engineers desirable to use a tolerably quick-setting concrete in preference to one which, though ultimately stronger, would stand a greater chance of yielding while yet in a green state. The concrete adopted in accordance with this view, for the lower half of the walls and entrance, consisted of 7 parts of broken blaize and sand, to 1 part of cement. The proportion of sand to

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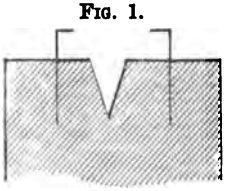
blaize was varied from time to time, depending upon the quantity of small particles amongst the blaize, the object aimed at being to have only just as much sand as was required to fill the interstices. In the upper part of the work the necessity for a quick-setting concrete was not so apparent, and on the other hand it was desirable to have a strong material with a hard skin to stand the chafing of vessels, &c. On this account practically no blaize was used, the concrete being formed of broken whinstone and sand. In all the concrete, while it was still soft, large rough stones were placed, the stones being left sticking up through each layer to form a bond to the next.

The layers were about 4 feet in thickness, and the ends were always finished plumb with a tongue to bond one length to the next, and old rails and chains were bedded in the concrete to form an additional tie (Fig. 1). The temporary planking for containing the concrete was accurately fitted, the inner faces being planed and coated with boiled oil where used above the change of batter of the wall. The finer concrete was kept to the front of the wall, and worked down by shovel, the consequence being that, when the planks were removed, the wall presented a smooth face like polished ashlar. The sand was nearly all obtained at different places on the shores of the Firth of Forth, a great portion coming from the Drum sands, 9 miles from Bo'ness. It was clean and sharp, no dirty material being allowed. The specification stated that the engineers would prefer the concrete being mixed by machine; but that if hand-mixing was adopted, the materials were to be turned three times while dry, and twice after the water had been added. The contractor elected to do all the mixing by hand; and in the Author's opinion it was satisfactorily done, although he doubts the economy of the proceeding.

Fig. 1.



The ordinary section of dock walls is shown in Plate 13, Fig. 8. It was built on an open timber platform resting on piles. The wall is 19 feet wide at the base, 38 feet high, and is finished with a granite coping. Timber fenders, 6 feet apart, are bedded in the concrete and fastened with joggles. The wall in all cases rests on piles 15 feet long, spaced 4 feet apart from centre to centre. The pile-heads are tied together transversely with two walings, 12 inches by 6 inches, and longitudinally by whole-timbers notched over the pile-heads. There is no planking, the concrete being packed in between and round the timbers. In the ordinary

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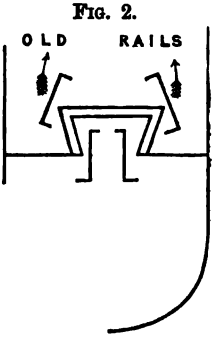
section the level of the bottom of the concrete is 8 feet below the bottom of the dock, but it was frequently necessary to carry the concrete lower to reach a tolerably solid bed. It should be mentioned that the foundations were supported by sheet-piles back and front. The front piles, 23 feet long, were driven to 26 feet below the bottom of the dock; the back piles were half-timbers 18 feet in length, being intended only to keep up the bank while the foundations were got in; however, both back and front piles were left in. As the clay was of a soft and plastic nature, the pile-driving did not improve the foundation by consolidating the ground, the clay being simply displaced in proportion to the space occupied by the piles. The object chiefly aimed at in using the piles was to overcome the tendency of the walls to slide forward. In the Author's opinion the piling proved of great use in this respect. In taking out the excavation, the ground behind the wall was stepped at a slope of 2 to 1, and as the wall was built the space was backed up with blaize, ashes, slag, or other dry material deposited in 2-feet layers next the wall. The Author believes that the method employed in backing up a wall has a great deal to do with the relative strength of the section employed; and yet he has noticed that, in the majority of published descriptions of work, no mention is made either of the material used, or of the manner of its deposit. It may also be remarked that a proper description of the substrata is very important.

The specification for the Bo'ness Dock provided, amongst other matters, that all the walls of the dock were to be raised to half their height before any part of them was taken higher. This stipulation was practically adhered to with great advantage to the work. The whole of the walls sank about 6 or 8 inches during construction, and if the weight had not been so uniformly applied, no doubt cracks and dislocations would have been numerous. On the south side the longest wall of the dock, 860 feet in length, does not show so much as a hair crack, and the few cracks which appeared on the north side were due to the sliding of the wall. The dock walls are not connected with the entrance walls but are tenoned to them to prevent outward motion of the free end (Fig. 2). A space of 3 or 4 inches is left between the mortice and tenon, which is filled with puddle clay to prevent the escape of water, and this space is tapered vertically, so that an unequal settlement tends to compress

FIG. 2.



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the clay in the joint. The taper is upwards on the back of the mortice, and downwards at the sides; thus either part of the wall in sinking would compress the clay sufficiently to ensure a tight joint.

Shortly after the north wall was finished, the east length, being the recessed berth, showed signs of a forward movement, and the backing which was then proceeding was stopped for a few months to allow the wall further to consolidate. During the time when no backing was being deposited behind the wall no further movement took place; but as soon as tipping was recommenced, although nothing was deposited within 50 feet of the wall, it again began to slide. Chains had been put in tying the wall to the river wharf or dam, and these to some extent checked the motion at the top, but the wall began to move faster at the bottom: three of the chains however gave way, so that the movement still continued at the top though to a less extent.

It was then decided to put in a heavy toe, and this was accordingly done (Plate 13, Fig. 7). In excavating for this toe it was found that the front sheet-piles were leaning forward, the overhang being equal to the extent of the movement. The piles were perfectly straight, showing the small amount of resistance opposed by the clay, and that the piles must have been of considerable benefit in increasing the friction of the base of the wall. Had the piles been longer at this particular place, possibly a sufficient resistance might have been attained, but increased depth and weight of wall would have been the surest remedy. The toe was put in, in short lengths, as quickly as possible, after which the numerous cracks in the wall were grouted, and to overcome the unsightly appearance of the consequent curve on the coping the wall was timbered as shown in Plate 13, Fig. 7. The movement of this wall is rather remarkable considering the heavy section, and that the material used for filling as far as 80 feet back from the wall was particularly favourable. The cost of the ordinary wall was £26 15*s.* per lineal foot, including the excavation, dry backing, punning, &c. It seems only fair, in stating the cost of a wall, that these items should be assumed to be part of the expense of the wall. Plate 13, Fig. 9, shows the section of the wall of the entrance basin. This differs from the dock-wall as it had nearly all to be done by tide-work, and heavy sheet-piling kept up to the top of the mud was necessary to allow of the foundations being satisfactorily got in. This quay was made rather heavier than the dock-wall, as it has not the support of a constant head of water, and because the foundation was not so good. At the point of crossing No. 1 dam,

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where the piles of the dam were allowed to remain, a slight unequal settlement has occurred.

A plan and sections of the entrance are shown in Plate 14, Figs. 10, 11, 12 and 13. There is no lock, it having been considered that the size of the dock hardly justified the large expenditure which would have been required; and as the gates can be kept open for about three hours at high water the advantages of locking would not have been very great. The entrance sills and aprons are perhaps thicker than usual, because sinking was sure to take place, and the great weight of the side walls would have been apt to cause an unequal settlement. By keeping the whole of the entrance work one solid mass, unconnected with the walls, fractures or dislocations have been entirely avoided. The entrance has sunk about 4 inches altogether. As is shown in the longitudinal section (Fig. 11) the thickness of the sill proper is 13 feet 6 inches, namely, 5 feet of granite invert, 2 feet 6 inches of brick in cement, and 6 feet of concrete. Below the pointing sill, however, and at the two ends of the aprons, cross-walls are taken down to a greater depth, that at the outer end being 18 feet 6 inches below the level of the top of the sill. These two outer cross-walls are between two rows of sheet-piling 15 and 23 feet in length, and sheet-piles 30 feet long are carried completely round the entrance at the back of the side walls to maintain the banks during construction and to provide for equal settlement. The gates (Plate 14, Figs. 14 and 15) are entirely of greenheart, and have been carefully fitted and hung (Fig. 3, p. 370), the consequence being that they can be opened or shut with a very small amount of labour if the hydraulic apparatus is not in use. The presses are hydraulic rams, multiplying four times, the chains being taken round rollers to the fast ends on the gates in the usual manner. The entrance is fitted with sluices, and has four heavy ship capstans.

The trade of the port consists of the export of coal and the import of timber, pig-iron, and general goods. The coal-traffic is provided for by three hydraulic hoists or tips, the general arrangement of which is shown in Plate 15, Figs. 18, 19, and 20. They were designed by the makers in compliance with a specification stating the requirements. The cradles are carried by six steel-wire ropes, which pass round pulleys on the cradle, on the fixed part of the hoist, and on the hydraulic presses, of which there are two, one press at each side; thus the outward stroke of the ram necessarily reduces the distance between the cradle and the fixed pulleys. As all the coal-wagons in the district open only at the end, the cradle must allow tipping, and this is accomplished by a direct-

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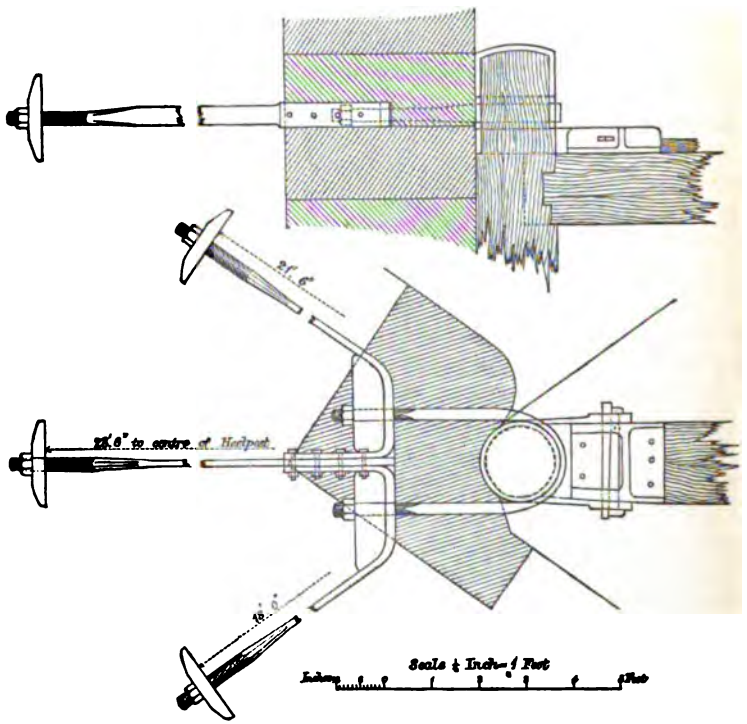
acting tipping-press attached to and travelling with the cradle, the connection being made by an elbow-jointed pipe. The advantage claimed for this construction of hoist is that it almost dispenses with the necessity for foundations, all that is required being two blocks of concrete for the back legs and an iron casing for the cradle. As these blocks were on ground liable to settlement, wedges were provided under the back legs of the hoist to keep the framework vertical. It is doubtful, however, if the saving

FIG. 3.



attained by the abolition of heavy foundations is sufficient to justify incurring the extra risk entailed by the use of ropes for carrying the cradle. The cradle and load together weigh 22 tons, of which about 10 tons, being the weight of the cradle and part of the wagon, are balanced by weights attached to the end of the rams. The breaking strain of each rope is 22 tons, and as the ropes are double there is a total factor of safety of 12. Two of the coal-hoists being at the end of the dock the rails lead direct

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on to the cradle; at the third berth every wagon has to make a quarter revolution on a turntable. Turn-tables and capstans have, however, to be provided at each hoist, as the wagons only open at one end, and they frequently come wrong end foremost. At one of the berths at the end of the dock the rails have been laid on gradients sufficient for the wagons to run by their own gravity on to the cradle when loaded and away from it when light. This system is largely in use at ports in the north of England. At this berth a hydraulic turntable has been applied to save time and labour in turning the wagons by the capstan rope.

The table is slewed by hydraulic presses, which actuate a chain passing round a wheel on the shaft of the table; and separate short direct-acting presses tip up one end of the table to send the wagon onwards to the hoist. By this hoist four men can ship twenty to thirty wagons per hour, doing all the labour required from the time the wagons are left by the locomotive. The total cost of shipping is 1·48*d.* per ton, of which details are given in Appendix III.

The Author has made a comparison between the cost of shipping coal by the hydraulic-hoist system and by the high-level staiths common on the Tyne and Wear, and this also is shown in Appendix III. It will be seen that in point of economy the system at Bo'ness does not compare unfavourably with the staiths; but of course a greater speed of shipment can be attained with the high-level spouts when combined with the hopper-wagons in use in the north of England. On the other hand, the absence of heavy iron or timber gearing, by leaving the quays available for general traffic when not required for coal-shipping, renders the low-level system probably the most suitable for ports where there is a general trade. The greatest speed attained by the hydraulic system, within the knowledge of the Author, has been at Burntisland, where shipping has been carried on for a short period at the rate of forty wagons per hour. This speed could have been maintained but for the fact that the vessel could not be trimmed to keep pace with the loading. Self-trimming vessels are, however, coming into use in the coal trade, so that it will probably soon be possible to maintain a higher rate of shipment than is at present attainable. At many ports in Scotland coal-shipping is still carried on by steam cranes, but the success of the hydraulic system, first introduced into Scotland at Burntisland, has been so marked that there can be no doubt cranes will not be often applied to this purpose in future. The high-level system is most applicable when the land close to the shipping places is high; but

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where the cost of the gearing required would exceed £8,500 for each berth it would probably be cheaper to adopt the low-level mode of shipment. As it is of great importance in the shipping of coal expeditiously to have the cargoes of vessels expected waiting their arrival, a large amount of railway sidings has been provided, there being 1,500 yards to each hoist, and ground is available on which additional railways can be laid.

The other trade of the dock is provided for by portable hydraulic cranes running along the edge of the quays, and sheds have been erected for storing general goods, esparto grass, &c. Capstans are also placed round the dock for moving railway trucks, as it is intended to work all the traffic without horses. The floor of the general goods shed is on the level of the floor of a railway truck, so that there is a minimum of labour in trucking or unloading goods. The sheds are fitted with 30-cwt. hydraulic station cranes. All the machinery is hydraulic, the power being supplied by a compound engine pumping water at a pressure of 700 lbs. per square inch into a steam accumulator. Steam is supplied to the engines and accumulator by two steel boilers of the Cornish type, working at a pressure of 80 lbs. per square inch. The engines and accumulator were supplied by Messrs. Brown Brothers and Company, who also furnished the coal hoists, gate machinery, and some of the cranes and capstans. The shed-machinery and the remainder of the capstans and cranes were from the works of the Hydraulic Company of Chester.

The works remaining to be carried out to complete the original scheme are the extension of the piers and the formation of the timber pond.

Increasing the size of the dock to 7½ acres raised the estimate for this part of the work to £180,000, making a total estimate of £255,000. The works up to the present time have cost £200,000, as follows:—

	£
First length of West Pier	12,000
,, ,, East Pier	18,000
Dock	170,000
	£200,000

About £40,000 additional will be ample to finish the piers and timber pond. It will be noticed that there is a saving of £10,000 on the dock alone—a result which has been attained through the low prices at which some of the work has been taken.

The dock was opened for traffic on the 3rd of December, 1881.

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The contractor, Mr. T. S. Hunter, died in February 1880, since which time the work has been carried on by his trustee.

The resident engineer from the commencement has been Mr. F. Jopling, Assoc. M. Inst. C.E., and the contractor's engineer, Mr. J. L. Houston, Assoc. M. Inst. C.E., to both of whom the Author is indebted for assistance in preparing the Paper.

The Paper is accompanied by several drawings and sketches, from which Plates 13, 14, and 15, and the woodcuts, have been prepared.

[APPENDIX.

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APPENDIX I.—Crushing strength of Concrete Blocks made of various materials, the proportion of Cement to the other materials being as 1 to 7.

I. Blocks 6-inch cubes and six weeks old.					*II. Blocks 9-inch cubes and nine weeks old.*					*III. Blocks 9-inch cubes and twenty-three weeks old.*				
No. of Block.	Crushing strain in lbs. per square inch. Whinstone and sand.	Blaize and sand.	Other Materials.	Remarks.	No. of Block.	Crushing strain in lbs. per square inch. Whinstone and sand.	Blaize and sand.	Other Materials.	Remarks.	No. of Block.	Crushing strain in lbs. per square inch. Whinstone and sand.	Blaize and sand.	Other Materials.	Remarks.
1	703	..	..	Damp in centre	13	628	..	..	Drum sand and gravel.	25	..	890	..	
2	746	..	..	" "	14	..	..	234		26	..	890	..	
3	..	1,318	..	Dry right through.	15	..	768	..		27	..	572	..	
4	..	691	..	" "	16	..	..	..	Broken accidentally.	28	..	826	..	
5	..	..	703	Slightly damp in centre.	17	..	..	..	" "	29	..	636	..	
6	..	703	..	Dry.	18	..	703	..		30	..	763	..	
7	526	..	..	Damp in centre	19	..	..	742	Clean sharp sand and shells.	31	763	..	..	
8	..	..	..	Broken accidentally.	20	..	..	625		32	763	..	..	
9	..	..	526	Slightly damp.	21	768	..	..		33	954	..	..	
10	351	..	..	Damp.	22	..	..	312	Ballast not quite clean.	34	890	..	..	
11	..	966	..	Quite dry.	23	..	586	..		35	..	890	..	
12	..	..	..	Broken accidentally.	24	796	..	..		36	..	..	763	
	2,326	3,678	1,229			2,192	2,057	1,913			3,370	5,467	763	
Average	581	919	614	Blaize blocks average 58 per cent. stronger than those made of whinstone.	Average	730	685	478	Whinstone blocks average 2 per cent. stronger than those made of blaize.	Average	842	781	763	Whinstone blocks average 8 per cent. stronger than those made of blaize.

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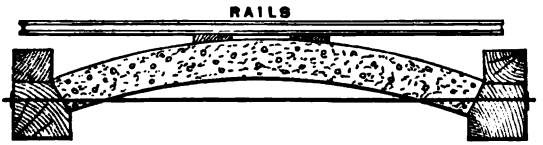
APPENDIX II.

EXPERIMENTS on the STRENGTH of CONCRETE, COMPOSED of DIFFERENT MATERIALS in the FORM of BEAMS and ARCHES.

The arches were formed between wood springers tied together by two tie-rods 1¼ inch in diameter, and were of the following dimensions: 8 feet 3 inches span, 1 foot 9 inches wide, 9 inches thick, with 9 inches rise at the crown.



Arch No. 1.—The materials used in the construction of this arch were burnt blaize and sand from Queensferry, gauged in the proportions of 5½ parts of burnt blaize, 1½ part of sand, and 1 part of cement.

Testing was commenced when the arch was sixty-one days old, by loading it with rails, the load being distributed over a distance of 2 feet 6 inches at the crown. Under a load of 4 tons a slight crack appeared on the underside; the weight was increased to 6 tons and testing discontinued for the day. On the following day the load was increased to 12½ tons, under which the arch gradually sank, till on the fourth day the rails rested on the chocks, having sunk about 1½ inch. The weight was then removed, and, although the upper portion of the crown was partially crushed, the arch had not fallen. The concrete was dry throughout.

Arch No. 2.—The materials used in this arch were whinstone chips from the quarries at North Queensferry, and ballast from South Queensferry, gauged as follows:—4½ parts of whinstone chips, 2½ parts of ballast, and 1 part of cement.

Testing was commenced when the arch was sixty-seven days old. When a load of 2 tons was reached the arch showed signs of weakness, cracking in several places on the underside. Under a load of 8½ tons the arch completely failed by crushing at the crown, and fell between the springers about two hours after commencing the test. The concrete was damp in the centre.

Beam No. 1.—This beam was composed of burnt blaize and ballast in the proportions of 4½ parts of blaize, 2½ parts of ballast, and 1 part of cement. The dimensions were 2 feet 6 inches by 6 inches by 6 inches, and when tested it was placed on supports having a clear span of 2 feet 2 inches.

Testing was commenced when the beam was thirty-five days old, and it broke under a load of 468 lbs. applied at the centre.

Beam No. 2.—This beam was composed of whinstone chips and ballast in the proportion of 4½ parts of whinstone chips, 2½ parts of ballast, and 1 part of cement. The beam was supported as before, and tested when thirty-nine days old, and it broke under a load of 307 lbs. applied at the centre.

The ratio of the strength of the two materials appears about the same in both cases (arches and beams).

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APPENDIX III.

Cost of Shipping Coal.

I. *Hydraulic Hoist system.*—Three hoists with self-acting arrangements similar to No. 3 hoist, Bo'ness.

The pumping establishment supplies power to cranes and other appliances round the dock, consequently only half the expense is charged to coal shipping.

A shunting engine is assumed to be capable of doing all the sorting required for 1,000,000 tons per annum where the self-acting gradients are in use.

Capital.

	£
Half the cost of engines, boilers and buildings	1,825
Three hoists and foundations	4,350
Capstans, pipes, &c.	860
Formation of ground, laying rails, &c.	6,000
	£13,035

Annual shipment = 600,000 tons.

Cost of Shipment.

Pumping establishment—

	£
Wages	153
Coals	150
Water	20
Repairs	50
Sundries	100
	£473

	Gross. £ s.	Per Ton. d.
One-half charged to coal shipping	236 10	0·093
Labour at hoists and sidings	1,500 0	0·600
Proportion of shunting engine at £600 per annum	360 0	0·144
Maintenance and repairs of railways and hoists	300 0	0·120
	2,396 10	0·957
Interest, 5 per cent. on £13,035	651 15	0·261
Depreciation at 5 per cent., which allows for complete renewal within fifteen years	651 15	0·261
	£3,700 0	1·479

II. *High-level staith system.*—Three high-level staiths with spouts and self-acting gradients similar to those in general use at the North of England ports; the height of the railways above the quay being 30 feet, and the length of gearing 300 feet to each spout.

Shunting engine as in former case.

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Capital.

	£
Cost of erecting three staiths of modern construction . .	15,000
Formation of ground, laying rails, &c.	6,000
	£21,000

Annual shipment = 750,000 tons.

Cost of Shipment.

	Gross. £	s.	Per Ton. d.
Labour at spouts	1,562	10	0·500
Proportion of shunting engine	450	0	0·144
Maintenance and repairs of railways and staiths	250	0	0·080
	2,262	10	0·724
Interest, 5 per cent. on £21,000	1,050	0	0·336
Depreciation at 2½ per cent., which allows for complete renewal in twenty-eight years	525	0	0·168
	£3,837	10	1·228

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(*Paper No. 1881.*)

"On the Recent Landslips in the Salt Districts of Cheshire."

By EDWARD LEADER WILLIAMS, M. Inst. C.E.

THE large landslips of recent occurrence in the neighbourhood of Northwich, and the more gradual subsidence that has been going on for the last fifty years in the greater part of the Cheshire salt districts, form a subject of considerable interest, particularly when considered in connection with the geology of the country, and the method by which the manufacture of salt is carried on.

Lakes are being formed, part of the towns of Winsford and Northwich have had to be rebuilt, and the locks, weirs, and bridges on the River Weaver Navigation have required to be re-constructed and re-arranged. The whole of the subsidence arises from the rock-salt beds which underlie the district being dissolved, and the brine thus formed being pumped to the surface, where by evaporation it is made into white salt.

Rock-salt has been considered by some geologists to be the product of volcanic agency, but it is now generally believed to be the result of deposit in super-saturated lagoons or lakes.

If a line be drawn from the estuary of the River Mersey through Cheshire, along the valley of the rivers Weaver, Dane, and Wheelock, and be thence continued through Shropshire and Staffordshire, to Stoke and Droitwich in Worcestershire, it will pass through all the principal rock-salt beds in England. This line also continuously traverses the marl and clay beds of the triassic system, formerly called the saliferous marls, which are evidently the result of sedimentary deposit.

There is no evidence of the beds of rock-salt in this country forming continuous strata over large districts; no outcrop of rock-salt is known in England. This has been accounted for on the grounds that the rock-salt has been dissolved; but if this were true, deep subsidence would show the lines of the original outcrops. No such change of surface level is, however, found where the rock-salt beds must have appeared at the surface had they been continuous. Supposing that successive elevations and submergences of the land took place during the formation of the marl and clay beds, and that evaporation at the same time was going on, it is easy to conceive that beds of salt would be formed in lake basins,

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and being afterwards subjected to great pressure, would take the form of rock-salt. The alternate beds of marl, clay, and rock-salt, the difference in the thickness of the various strata, and the circumscribed areas in which rock-salt is found, are all corroborative of this theory. The salt-beds would thus be formed at the lowest points of the original drainage area, and they are now principally found in the valleys of the rivers that drain the district.

The salt-beds at Northwich and Winsford occur in the following order, commencing at a level of 80 feet above ordnance datum :—

NORTHWICH.

	Feet.
Drift composed of sand and clay	27
Brown and blue marls with veins of gypsum	106
Rock-salt	84
Hard brown and blue marls	30
Rock-salt	84
Marls with thin veins of rock-salt	87
Rock-salt	3
Marls with thin veins of rock-salt	81
Rock-salt	6
Hard blue marl not sunk through	18
Total depth from surface	526

WINSFORD.

	Feet.
Drift composed of sand and clay	6
Variegated marls, with beds of hard marlstone and veins of gypsum	190
Rock-salt	15
Marlstone	3
Rock-salt	33
Hard blue marl	3
Rock-salt	69
Brown and blue marls with veins of rock-salt	35
Rock-salt	121
Brown and blue marls with veins of rock-salt	30
Rock-salt	3
Marls with veins of rock-salt	35
Total depth from surface	543

The salt district of Cheshire forms a large plain, situated in the new red marls, overlaid with boulder clay or sand.

The main drain is the River Weaver, which falls into the River Mersey near Runcorn. Winsford, now the principal seat of the salt manufacture, is situated on the first-named river, about 18 miles from the Mersey, and is the terminus of the Weaver

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Navigation. Northwich is 5 miles lower down the river, where it is joined by the River Dane, which is only navigable for a short distance; but on its banks, and those of its tributary the Wheelock, are the salt-works of Sandbach and Middlewich. Nantwich, originally the main seat of the salt trade, has long ceased to manufacture salt, owing to the brine having become weaker, and not having the great facilities of deep-water carriage that Winsford and Northwich now possess.

Cheshire contains a number of small lakes, locally called meres. Combermere is nearly a mile in length; Rostherne Mere is also of large size, and Tabley Mere, Oakmere, and others are considerable sheets of water. These meres have been considered by some geologists to have been formed by local subsidence, owing to the dissolving of rock-salt. If this were so, and the rock-salt beds were continuous, it might be supposed that the area of these meres would be constantly extending; but this is not the case, and neither by borings or otherwise has proof been given that the rock-salt beds extend so far from Northwich.

Most of the recent landslips are near shafts from which brine is pumped; others can be shown to have connection with them, by lines of subsidence. In addition to land-springs the River Weaver probably supplies water to the rock-salt to form brine. Near Northwich some old shafts are now submerged under the river, and at other places fissures have been formed by the ground sinking, down which river water can find its way. To a small extent, natural causes may induce subsidence in Cheshire, as elsewhere; the rivers carry away considerable quantities of various salts in solution to the sea. No salt-springs, however, now rise to the surface in the sinking districts, and if they did in former times, the land was not injuriously affected as now, the operations of nature being slow and gradual.

Near Nantwich some springs rise to the level of the ground, and flow into the River Weaver, but no subsidence takes place near these springs. The Author found the river, in times of ordinary flow, to contain 8 grains of chloride of sodium to the gallon, or more than eight times the ordinary amount in inland river-water in this country. At Northwich the River Weaver is charged with much more salt; also the River Dane, but this is due to the waste from the salt-works.

The large volume of brine pumped has reduced the height of the brine considerably below sea-level, and consequently in the Northwich and Winsford districts there can be no direct or indirect flow to the sea. The constantly decreasing height of the brine is

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shown by the records kept by Mr. H. E. Falk, at the Meadow Bank Works, near Winsford, which prove that the abstraction of brine by pumping is greater than the rainfall. The level in February 1865 was 99 feet below the surface; in February 1870, 118 feet; in February 1875, 132 feet; and in February 1880, 144 feet; the rate at which the brine lowers in level being almost uniform.

At Winsford twenty-eight and at Northwich eleven brine-shafts are worked, the brine being pumped to the surface by steam-power. Nine rock-salt mines are also worked, eight of which are near Northwich, and one near Winsford.

The brine used for salt-making, when of proper strength, contains about 2 lbs. 8 oz. of salt to the gallon, or 25 per cent., being nearly a saturated solution. It is more economical to pump the brine and evaporate it, than to raise the rock-salt, with its various impurities, and dissolve it on the surface. Its composition is as follows:—

	Per cent.
Chloride of sodium	96·70
„ calcium	0·68
Sulphate of lime	0·25
Water	0·63
Insoluble matter	1·74
	100·00

The proportion of chloride of sodium varies, to a small extent, and traces of magnesium and potassium are sometimes noticed.

The iron pans used for evaporating the brine are from 40 to 60 feet long by 20 to 30 feet wide. The most simple arrangement of flues is used, the plan generally adopted being the same as shown by drawings dated 1740. Many inventions have been tried at great cost, but only a few have been found capable of being worked economically. Different temperatures are employed in salt-making, varying from 100° Fahrenheit to the boiling point, according to the degree of fineness required; coarse salt is only drained on being taken from the pan; fine salt is dried in box moulds, and afterwards crushed.

The brine shafts are cased with iron cylinders; where brine is got from old mines, a shaft is sunk through the unworked rock-salt, from which a drift is made towards the mine. Owing to the great depth of brine considerable danger was formerly incurred when the drift approached the brine. This was generally let into the mine through a bore-hole, which gave the men just time to escape up the shaft before it filled. Of late, however, the borings

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have been made through an iron pipe, with a stop-valve and stuffing-box at the outer end, so as to prevent the brine escaping while the hole is being bored. When the boring is completed, the valve is closed and the stuffing-box removed; pipes are then led off to the pumps, the stop-valve remaining to regulate the supply of brine.

The quantity of salt manufactured increases yearly; the proportion made in the district is

	Tons per Annum.
Winsford	1,000,000
Northwich	500,000
Wheelock and Lawton	100,000
Middlewich	80,000
	1,680,000

The greater part is shipped at Liverpool for India, America, and the Continent. The average shipments to the East Indies alone are 1,000 tons per day throughout the year.

As it takes about 10 cwt. of coal to manufacture 1 ton of salt, the consumption of coal in the salt districts is very large. The cost of making salt varies with the cost of fuel, but it may be taken at present at about 5*s.* 6*d.* per ton; the royalty being 6*d.*, labour 1*s.*, rent and repairs 9*d.*, and coal 3*s.* 3*d.*

The weight of 1 cubic yard of rock-salt is 32 cwt., and a large quantity of brine is wasted in the manufacture. Taking the total weight of salt made, the loss of underground support, 1 yard deep removed yearly by pumping, covers an area of 250 acres. With so great an amount of abstraction going on constantly, without any supports being left, it is obvious that landslips must continually occur, and large tracts of land be brought below the drainage level of the district. As far back as 1873 the sinking was so extensive that the Home Office instructed Mr. Joseph Dickinson, Inspector of Mines, to inquire into the matter, and the result was a detailed and valuable report.[1]

The area affected by sinking, excluding some outlying portions, extends from Marston through Northwich and Winsford, towards Nantwich, mainly along the valley of the River Weaver. The subsidence is not continuous, and some parts sink much faster than others. The subsidence extends over a district about 16 miles in length, and 1 mile to 4 miles in width. As most of the land is agricultural, and is at present above the drainage outfall, it is not yet seriously damaged; but near Northwich and Winsford some

[1] Also Mr. Dickinson's report on the Inspection of Mines, Cheshire, 1881.

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hundreds of acres are submerged below the level of the River Weaver.

In addition to the general subsidence a number of old rock-salt mines have fallen in near Northwich, through brine having found its way into the mines. In the town of Northwich streets and houses are continually giving way; many of the buildings have been reconstructed on timber sills, and are tied together with bond timbers and iron rods, to enable them to be periodically lifted. Special by-laws have been sanctioned by the Local Government Board to meet the case. The streets are raised by the local authorities without reference to the owners of the adjoining buildings, who, under a late decision of the High Court of Justice, have to lift their houses to the altered level of the streets without compensation.

In 1860 the Author reported that the stone bridge over the River Weaver was in danger, and he constructed a wrought-iron girder bridge in its place, to enable the bridge to be raised when required. This latter operation has just been successfully carried out by Mr. L. B. Wells, M. Inst. C.E. The bridge over the River Dane has also been rebuilt with girders, and has since been twice lifted. The extensive landslip of December 1880 occurred at Dunkirk, near a point where the Wincham brook joins the River Weaver. This brook formerly ran into the river ½ mile lower down the valley, but its course is now lost in the bed of a sheet of water, over 100 acres in extent, formed by subsidence.

Fifty years ago a canal, with locks, ran close to the brook, and was used for conveying salt and coals to and from the river; it is now submerged, and the largest ship afloat might safely anchor there. Many landslips have occurred near here, but the one of 1880 was the most serious subsidence since 1838, when an old rock pit fell in, carrying with it part of some salt works, causing the loss of seven lives. Adjacent are a number of pits filled with water, the remains of former landslips, and as the brine in 1880 had been getting lower, it was feared that the support afforded by the brine to the upper strata being thus removed other casualties would occur.

The site of the new landslip is near the Wincham brook, underneath which the Platts Hill rock-salt mine, 15 acres in extent, was being worked. The mine was quite dry, and had no connection with any brine shaft; yet the effect of the landslip was not only to fill the mine, but also to raise the level of the brine in the neighbouring shafts 220 feet. The slip took the usual form of an inverted cone, and was about 200 feet in diameter. Down this

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chasm the brook commenced running, and as from previous sinking the level of the bed of the brook had fallen below the level of the River Weaver, that river commenced flowing up the brook to the land-slip. The scour of the stream gradually cut out the bed of the brook, until it was 10 feet deep and 40 feet in width. Along this channel the whole of the flow of the river passed into the landslip for twelve hours. Moreover, part of the navigation, 160 acres in extent, was lowered nearly 1 foot; about 1,000,000 cubic yards of water and 50,000 cubic yards of earth disappeared in the landslip, the site of which is now a sheet of water. The expulsion of a great body of air from below caused some singular phenomena. Water and mud were blown up 20 to 30 feet high, while for a considerable distance round small geysers threw up the soil. Air also escaped through the earth into the adjacent water-pits, which are several acres in extent, the water being kept in a state of ebullition, as if fires were burning beneath. This continued active for many hours, and did not altogether cease for several days. Large cracks opened out in the surrounding ground, and the high chimney-shaft, and part of the buildings of the adjoining salt-works of Messrs. Ashton, fell down. It might have been expected that such a great influx of water would weaken the brine. This, however, did not occur; the rapid solution of rock-salt soon restored the brine to its ordinary strength. The salt-works consequently were only stopped for a short time to allow of the brine becoming clear, and the loss of property was confined to Messrs. Ashton's salt-works, and the wagons, rails, and other plant in Platt Hill mine.

During the year 1881 the subsidences continued, and this year one of the principal brine-shafts, that of Messrs. Marshall, has fallen in, but no landslip has taken place on so extensive a scale as that of December 1880. At Winsford the streets and houses sink even more than at Northwich. The church has been lately taken down. A girder bridge, constructed in 1865 to replace a stone bridge, was lifted 4 feet in 1877, 9 feet 6 inches in 1879, and is now about to be lifted again 4 feet 6 inches, or altogether 18 feet in five years. Above this bridge two sheets of water have been formed by subsidence in the valley of the River Weaver, this area being over 100 acres; and another lake is now forming on the branch of the Cheshire Lines Railway.

The railways through the district suffer considerably. Part of the London and North-Western Railway between Winsford and Crewe has been repeatedly raised. The Winsford branch of the Cheshire Lines Railway was constructed so recently as 1866, and yet part of the line, originally level with the land, is now on an

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embankment 30 feet high, which is being continually raised. The Trent and Mersey, and the Shropshire Union Canals, have required constant care to maintain the bridges and embankments; but the River Weaver navigation has suffered most by subsidence, the works near Northwich having undergone great modifications in consequence of the sinking, and of the greater liability to flooding thus caused.

In 1790 the Marston salt-works were connected with the River Weaver by a canal, the water being maintained at a higher level by a lock and weir. In 1811 the lock and weir were removed, as the level had so altered that they were not required, and there is now 60-feet depth of water where this canal formerly existed, the total subsidence having been nearly 100 feet.

The Northwich pound of the navigation was maintained with great difficulty; three times the lock and weir sunk so as to be useless. These were rebuilt on different sites in 1827, 1836, and 1843. In 1859 the Author advised the removal of the last-constructed lock and weir, making the Northwich and Winnington pounds into one long level, also doubling the length of the weir at Winnington to facilitate the passage of flood-water. The constant sinking of the town of Northwich, and the improvement of the navigation, has caused a large outlay on the river works. In 1865, and again in 1871, the Author was instructed to report to the River Weaver trustees on the question of improvement that would allow of coasting vessels passing up to the salt-works; and the works then recommended are now drawing near completion under the charge of Mr. L. B. Wells, the total cost having exceeded £600,000.[1]

The result of the improvements has been to reduce the cost of carriage, and to lessen the height of floods. The subsidence of the salt districts, however, continues, and, as there is no remedy for the evil but ceasing to pump brine, the mischief will probably go on until great part of the land near the river is submerged.

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[1] "The River Weaver Navigation." By John Watt Sandeman, M. Inst. C.E. Minutes of Proceedings Inst. C.E., vol. lxiii., p. 261.

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(Students' Paper No. 142.)

"Dioptric Apparatus in Lighthouses capable of producing the required Vertical Condensation, and a determinate amount of condensation in Azimuth, by single agency."[1]

By ALAN BREBNER, Jun., B.Sc., Stud. Inst. C.E.

AMONG lighthouse characteristics there is one which has been called the "intermittent light," the distinguishing feature of which is a definite length of light and dark periods, with an instantaneous change from the one to the other without the waxing and waning which characterise the ordinary revolving light. When the duration of the dark periods is small in proportion to that of the light periods, the characteristic is styled occulting.[2] The intermittent light was originally obtained by means of eclipsing shades, the light continuing to burn behind the closed shades during the dark periods. In the case of the occulting light, where the eclipses are obtained by a cylinder sinking down round the lamp flame and chimney, the loss of light may become so trifling as $\frac{1}{8}$ or $\frac{1}{10}$, being equal to the ratio of the duration of the eclipse to the duration of the flash.

The amount of divergence in azimuth, due to the great breadth of the oil flame, is not so considerable as to have dissuaded the engineers to the Northern Lighthouse Board from maintaining the characteristic of intermittent light with the employment of dioptric apparatus suited to give determinate azimuthal divergence, and with an oil flame as light source. But, since the amount of

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[1] This communication was read and discussed at a meeting of the Students on the 13th of January, 1882, and has been awarded the Miller Scholarship.

[2] The following explanation is from the Admiralty List of British Lights—

Intermittent, or occulting. — A light suddenly and totally eclipsed. When light between eclipses visible less than 30 seconds, term occulting applied. When light visible longer than ½ minute, term intermittent applied.

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unavoidable divergence accompanied by waxing or waning for any kind of revolving light varies as the ratio $\frac{\text{diameter of light source}}{\text{diameter of apparatus}}$, it is plain that, a large apparatus being employed, the replacement of the oil flame by the electric spark not only ensures a great gain by reducing the vertical divergence, but also makes possible a much sharper separation between light and dark periods, when these are obtained by suitable dioptric apparatus. The value of this sharp separation would be most significant in the case of the occulting light where a short but unmistakable eclipse is required.

To obtain a determinate amount of azimuthal divergence, there has hitherto been employed straight prisms placed outside the Fresnel fixed-light apparatus, except in the case of the refracting drum of the apparatus at the Mull of Galloway.[1] The present Paper is intended to show to what extent the same effect can be obtained by single agency, and with suppression of the straight prisms, which have the disadvantages of occupying more space, occasioning additional labour in the cleaning, and further of offering two additional surfaces to be traversed by the light rays at the expense of considerable reduction in intensity.

Considering first the catadioptric rings of the ordinary fixed-light apparatus, suppose it be desired to make them condense every 30° in azimuth into 4°, in addition to giving the required vertical condensation. Let A B C (Fig. 1$_b$) represent the profile of one of these rings, say the first above or below the refractor in a second order apparatus of 700 millimetres focal distance.[2] This profile is adapted to send out from A B in a parallelised sheet of horizontal rays the divergent angle of rays incident on A C; and if CA_1 and BB_1 be in the direction followed by the extreme rays after reflection from CB, and A_1B_1 be parallel to AB, the emergent rays will still be horizontal and parallel, quitting the prism at A_1B_1 instead of at AB. Taking, then, the mean distance of the face AB from the vertical axis through the focus, the curve necessary to give in azimuth a condensation of 30° into 4° at this

[1] Minutes of Proceedings Inst. C.E., vol. lvii., plate 8, fig. 2; also pp. 116, 117.

[2] As reasons for assuming a second order apparatus may be given: the sufficiency of its focal distance to prevent damage to the glass apparatus arising from the heat developed in an electric spark of great intensity; the fact that it gives room for entry inside the apparatus; and that it has been recommended by the most eminent authorities on lighthouse matters in Britain. It may, however, be remarked that the system described in the Paper is applicable, no matter what be the focal distance of the apparatus, or what the source of light.

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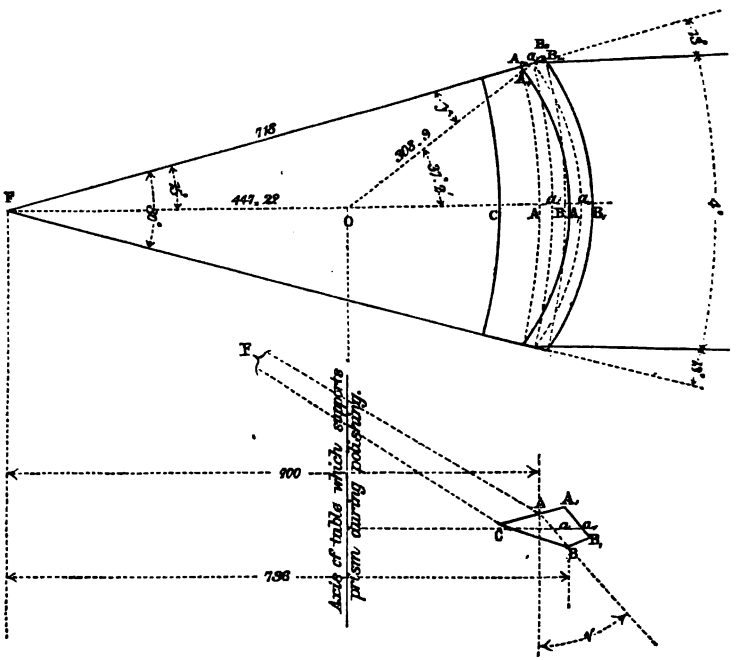
distance can be found. For denoting by Fa_{11} (Fig. 1*a*) this mean distance,

$$Fa_{11} = \frac{700 + 736}{2} = 718.$$

Fa_{11} represents in plan a ray which meets the outer face of a 30°-section at one extremity, and this ray has to be bent round 13°

FIGS. 1*a* AND 1*b*.



in azimuth. If, then, y be the incident horizontal angle necessary to give 13° of azimuthal deviation, and μ the index of refraction,

$$\tan y = \frac{\sin 13°}{\mu - \cos 13°}, \text{ and taking } \mu = 1{\cdot}53$$

$$y = 22°{\cdot}2'';$$

also
$$O a_{11} = 718 \frac{\sin 15°}{\sin (15° + y)} = 308{\cdot}9,$$

$$F O = 718 \frac{\sin y}{\sin (15 + y)} = 447{\cdot}22,$$

$$a a_1 = F O + O a_{11} - F a_{11} = 38{\cdot}12.$$

Now for the polishing of the outer face of prisms such as this,

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several sections would be placed on a round table turning about a vertical axis traversing the point O (Fig. 1*a*); so that, as the table turned carrying the prism along with it, the point a_{11} would follow the point a_1, and move in the same path. If now the polishing piece give the correct inclination at $A_1 B_1$, it will give this inclination also at $A_{11} B_{11}$, since as table and prism turn, and a_{11} arrives beneath the polisher at a_1, the points A_{11} and B_{11} take the places of A_1 and B_1. Hence $A_{111} B_{111}$, which lies in a vertical section through the focus, and which ought therefore to receive the same inclination as $A_1 B_1$, will not receive this inclination; but calling v the angle between AB and the vertical (Fig. 1*b*), and y the angle $Fa_{11}O$ (Fig. 1*a*), $A_{111} B_{111}$ will be inclined to the vertical at $\tan^{-1}(\tan v \sec y)$.[1] This inclination will be the most altered from the correct one, whilst between either extremity of a 30°-section and the middle the false inclination will approach gradually to the true one, until in the middle it coincides with it. The amount then of this false inclination varies as sec y, and it would have the effect of sending out the vertical sheet of rays at either extremity, and to a less and less extent at each vertical section on approaching the middle, at a dipping angle for the lower and a rising angle for the upper rings. The maximum difference of inclination of the emerging rays for a section of prism requiring to condense 30° into 4° would be 2°, and would occur in the rings immediately adjacent to the refractor, above or below; for condensation of 10° into 4° it would only be 6′; whilst for the highest ring of the cupola these values of 2° and 6′ are reduced to 17′ and 1′ respectively. For condensation of 10° into 4° the value of the angle y is 5° 37′, and it may be well to note how inconsiderable the difference of inclination becomes as the condensation diminishes.

Again, it may be seen in Fig. 1*a* that the ray whose projection is FA_{111} meets the outer face at an angle of incidence $OA_{111}F$ greater than, while the ray whose projection is FB_{111} meets it at an angle of incidence $OB_{111}F$ less than, the angle y, which corresponds to the ray whose projection is Fa_{11}, and which suffers 13° of deviation. From this cause the first ray would be deviated about 45′ more, the second 45′ less than 13°. The effect of this on the appearance of the light at sea would evidently be to give

[1] This is an approximation which gives a slightly greater inclination to $A_{111} B_{111}$ than it would actually have, but the difference is trifling. The angle $O B_{11} B_{111}$ is considered equal to 90° instead of to $90° - \frac{B_{11} O B_{111}}{2}$. (Fig. 1*a*).

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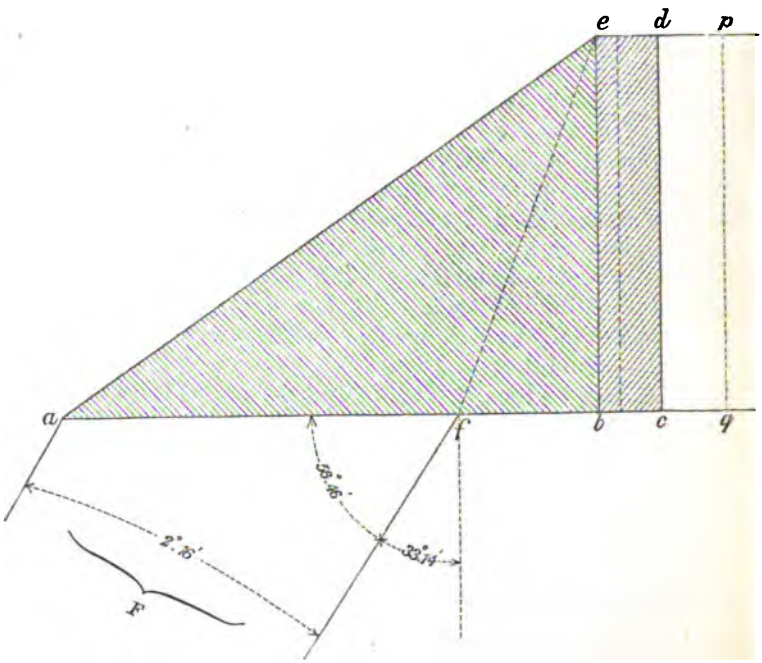
a waxing and waning appearance similar to that due to a flame of large diameter. It is less on ascending to the higher rings of the cupola, since the inclination of AB (Fig. 1*b*) becomes nearly vertical, so that A_{111} and B_{111} (Fig. 1*a*) approach towards a_{11}. Further, the amount of this defect varies with the angle y, and becomes inconsiderable for small angles of azimuthal deviation.

Now the difficulty in the execution of the form of prism here aimed at consists in the fact that the outer face is conical, whilst the axis of the cone is not coincident with the vertical axis through the focus. This difficulty is removed by giving to the outer face a vertical cylindrical surface, and forming the other two so as to direct the light rays horizontally on to the first-mentioned. Hence the first refracting side of the profile becomes horizontal, while the reflecting side is a circular arc of slight curvature calculated to direct the extreme incident rays horizontally. Fig. 2 shows

FIG. 2.



the full-size profile of a prism at half the height of the cupola. F *a q*, F *f e p* are the paths of the extreme rays. With this form of prism any desired condensation in azimuth can be given, the

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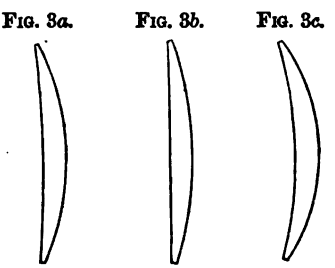
thickness *e d* of additional glass at the middle section being greater the greater the condensation required, while the triangular profile *a b e*, which is the lateral section of the prism, would be constant. The triangle *e f b* serves to connect *e b c d* to *a e f*, thus saving the necessity for light rays passing through two additional surfaces, as they must do when straight prisms are employed outside the fixed apparatus. With this form of prism both the objectionable effects of difference of divergence, horizontal and vertical, which accompany the modified form of the existing profile, disappear, and the full benefit of the sharp cut-off between light and dark periods possible with the electric light is obtained. The angles of incidence on the first refracting side of the new are greater than the corresponding angles for the present profile, but the angles of departure are less, being equal to zero for the new profile. Thus for the lowest ring of the cupola these angles are 52° and 0° for the new, as compared with 36° 12′ and 39° 12′ for the existing profile; for the highest ring they become 9° 47′ and 0° as against 6° and 9°; the lowest and highest rings of the cupola are here considered as placed at angular distances of 38° and 80° 13′ above the focal horizontal plane.

The maximum additional thickness of glass is shown (Fig. 2) for condensation of 15° into 3° (*e d*), for condensation of 30° into 4° (*e* to outer dotted line), of 10° into 4° (*e* to inner dotted line). Fig. 10 shows the cupola and lower set of reflecting rings of the new profile.

For the refracting drum three methods of obtaining azimuthal condensation have been considered, namely, that of taking the perpendicular through the focus as the axis of rotation for generating the curve of the outer face and of flattening the inner face



(Fig. 3*a*); that of taking the inner surface plane and the outer surface convex (Fig. 3*b*); and that of taking a perpendicular through the focus as the axis of the inner cylindrical face, and giving to the outer face the curvature adapted to the condensation

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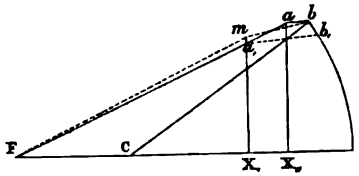
desired (Fig. 3*c*). In each case the outer face is supposed to have in the vertical direction the curvature suited to emit horizontal parallel rays.

In connection with the first form, consider the ray incident at

FIG. 4.



the outer summit of a division of the central zone at either extremity, then (Fig. 4):—

$$\text{the first angle of incidence} = a\,\mathrm{F}\,\mathrm{C},$$

$$\text{,,} \quad \text{,,} \quad \text{,, refraction} = \sin^{-1}\left(\frac{a\,\mathrm{F}\,\mathrm{C}}{\mu}\right);$$

while, C *b* being the radius of vertical curvature for the outer face, *a b* C is the angle of incidence previous to emergence. Now for a vertical section through the middle of the prism, the inner side of the profile *m* X is nearer the focus, and, C *b* being at the same inclination, the first angle of incidence is no longer = *a* F C, since the refracted ray at this angle follows the path $a_1\,b_1 \parallel a\,b$, whilst the ray incident on the outer face at *b* is the once refracted ray due to a greater angle of incidence *m* F C. Hence the incident angle previous to emergence at the middle, namely, *m b* C, is less than that at either extreme lateral section, namely, *a b* C, and consequently rays issuing from the middle section would differ in inclination from those leaving lateral sections. This effect would come into play also for the second form (Fig. 3*b*), and in both these forms of profile (Fig. 3*a* and Fig. 3*b*) the dipping angle, which lateral rays from zones above the focal plane would have, would be increased still more on account of each vertical sheet of light other than that at the middle, being incident on the outer face at an angle in azimuth, previously called *y* (Fig. 1*a*), to the section which receives the normal curvature.

Now in the third form of prism (Fig. 3*c*) the focal distance of the inner face is constant. Thus if *b a* F X (Fig. 5) be the vertical section through the focus and the side of a prism, and *c a* F X the corresponding middle vertical section, the inclination of the radius is the same for the middle at b_1 as for the side at *b*, *b* and b_1 being at the same level. Hence the ray incident on the outer face at b_1

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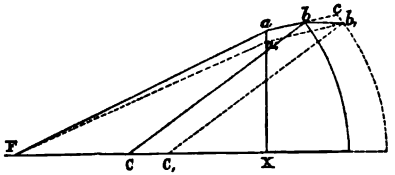
has a greater angle of incidence than that which falls on the outer face at b, for the former is equal to

$$b\,C\,X - \sin^{-1}\left(\frac{a_1\,F\,C}{\mu}\right), \text{ while the latter is equal to}$$

$$b\,C\,X - \sin^{-1}\left(\frac{a\,F\,C}{\mu}\right).$$

Thus the incident angle being greater at the middle section from this cause, while from the effect in the horizontal plane it is less

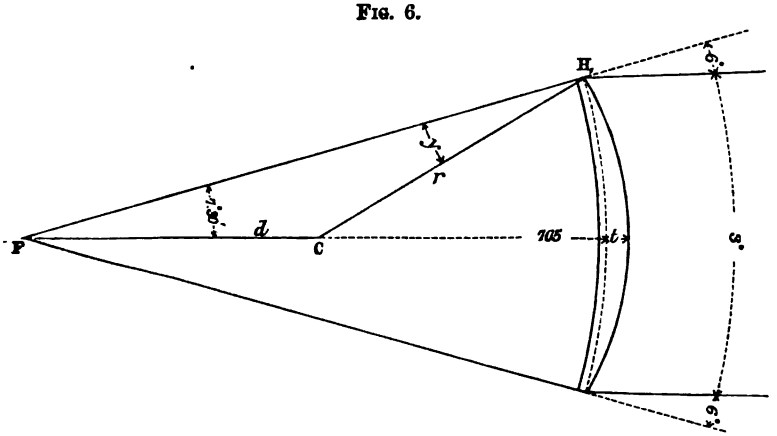
Fig. 5.



than at a lateral section, the two effects tend to counteract each other, and this form has the advantage over the other two.

Before giving a Table of the results of calculations made for a refractor of the third form, to find the inclination of axial and lateral emerging rays for compartments in azimuth of various extent, and for various amounts of azimuthal condensation, a design for an apparatus condensing every 15° in azimuth into 3° will be described.

Fig. 6.



Consider (Fig. 6) the projection on the horizontal plane of a horizontal section through the lateral summits of a 15° compartment of any refracting zone, and of the focal rays passing to either

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extremity. This projection is approximately common to all the zones of the refractor. Adding 5 millimetres to the focal distance of 700 for the thickness of a lateral joint at the top of a zone F $H_1 = 705$. The ray F H_1 must suffer a deviation of 6°, and for this purpose

$$y = \tan^{-1}\left(\frac{\sin 6^\circ}{\mu - \cos 6^\circ}\right) = 11^\circ\ 3'.$$

$$\text{Angle } H_1 F C = \frac{15^\circ}{2} = 7^\circ\ 30'.$$

Hence, as the side F H_1 is known, and the angles of Δ F H_1 C,

$$d = 424{\cdot}75,$$
$$r = 289{\cdot}25,$$
$$t = d + r - 705 = 9{\cdot}0.$$

Thus the horizontal thickness of a zone at the level H_1 in the middle vertical section $= 9 + 5 = 14$.

Let Fig. 7*a* represent the middle vertical section of any refracting zone. The heights h, h_0, and the focal distance f, are known.

Hence at H

$$\text{the first angle of incidence } I = \tan^{-1}\left(\frac{h}{f}\right),$$

$$\text{,, ,, ,, refraction } R = \sin^{-1}\left(\frac{\sin I}{\mu}\right).$$

The height of H_1 above the focal plane $= h + 5 \tan R = h_1$.

The level H_1 is that of the highest point at a lateral joint of the zone; at the middle vertical section H_{11} is the highest point; but in order to find the difference of vertical inclination of emerging rays at the middle, and at either side, it is expedient to consider the ray which leaves the middle section at B_1, that is, at the level H_1. Calling B F X, the first angle of incidence of this ray, I′, and its first angle of refraction R′,

$$I' = \sin^{-1}(\mu \sin R'),$$

while R′ is obtained tentatively from the equation

$$f \tan \sin^{-1}(\mu \sin R') + 14 \tan R' = h_1$$

in which R′ is the only unknown quantity.

The inclination of ρ to B B_1, in order that ray F B B_1 may issue horizontally, can now be determined; for

$$B B_1 O = \tan^{-1}\left(\frac{\sin R'}{\mu - \cos R'}\right).$$

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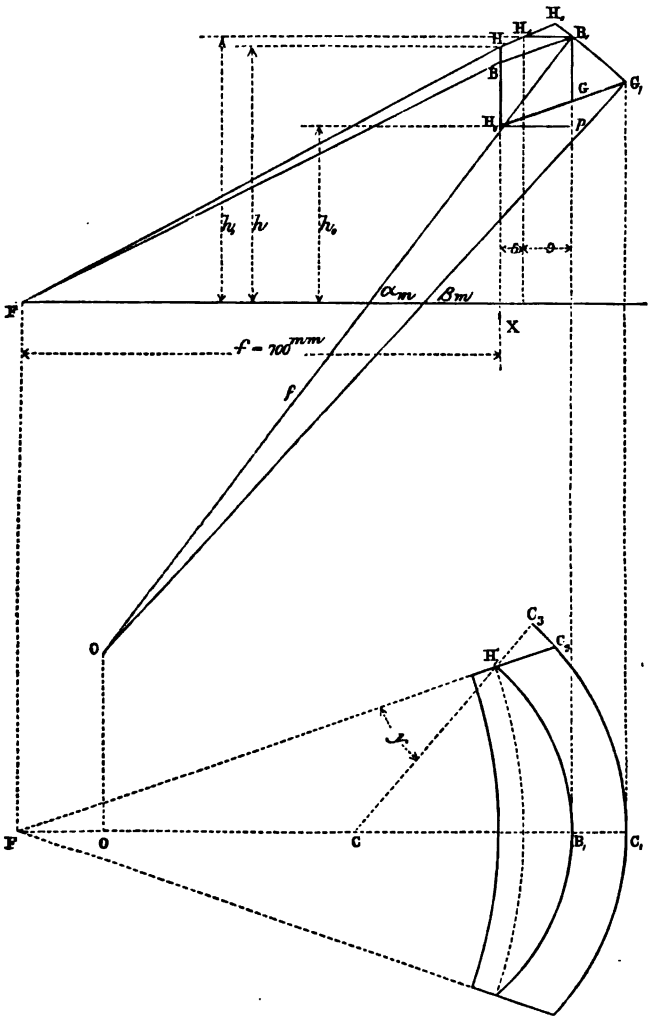
Then for the inclination of ρ to the horizontal plane

$$\alpha_m = B B_1 O + R'.$$

Now considering (Fig. 7*b*) the projection on the horizontal plane

FIGS. 7*a* AND 7*b*.



of a horizontal section through H_1, O C B_1 is the projection of the vertical plane in which ρ, the radius of vertical curvature for the outer face, moves. Hence, as the table on which the prism rests

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during the polishing turns about C, the centre for horizontal curvature, and carries the prism along with it; the point C_3 arrives beneath the polisher at C_1, when H_1 is beneath it at B_1, so that the curvature of B_1C_1 is given at H_1C_3, while the curvature at H_1C_2 is more pronounced. Calling α_s the inclination to the horizon of the radius of curvature at H_1 in the vertical section whose projection is H_1C_2, it will be seen that

$$\tan \alpha_s = \sec y \tan \alpha_m.^1$$

Hence α_s is found, and as the inclination of the ray in the glass, previous to its issue at H_1, has been called R, the angle of internal incidence of this ray $= \alpha_s - R$, and its angle of emergence $= \sin^{-1}\{\mu \sin (\alpha_s - R)\}$. Thus, knowing the direction in which the ray leaves the zone at H_1, and that the corresponding ray at the middle section emerges horizontally from B_1, the difference of inclination between the two is obtained. In this way the values of this difference have been found for all the zones of the refractor. Calling the central zone 1, and the highest or lowest 11, these values are shown in the second column of Table I., for zones 3 to 11; for the central zone it is 7′, and for zone 2 it is 10′.

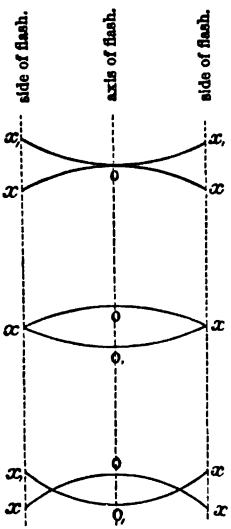

Fig. 8a. Fig. 8b. Fig. 8c.

If now the differences of inclination between rays issuing from a prism at each vertical section passing from one side to the other of a 15°-division be taken as ordinates, and the corresponding angular distances of the sections from the middle as abscissæ, a curve is obtained of the form $x\ o\ x$ (Fig. 8a). If rays leaving the middle section be horizontal, then for zones above the focal plane rays leaving the lateral sections dip; for zones below the focal plane they rise; and (Fig. 8a) $x\ o\ x$ representing a sheet of light from one of the former, $x_1\ o\ x_1$ will represent that from the corresponding one of the latter.

If, however, rays from the sides be horizontal, rays from the

[1] This formula is exact for the refracting rings. If the maximum difference of inclination for any other level on the same zone be determined it will be found sensibly the same; hence the difference found for the level of H_1 may be taken as that for the zone to which it belongs.

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middle rise for zones above, and dip for zones below, the focal plane, and (Fig. 8*b*) $x\ o\ x$ representing light from an upper, $x\ o_1\ x$ will represent that from the corresponding lower zone.

Again, if rays from the middle rise half the maximum difference, rays from the sides will dip for the upper, and rise for the lower, zones by half the maximum difference; and the simultaneous effects may be represented by $x\ o\ x$ and $x_1\ o_1\ x_1$ (Fig. 8*c*).

If the light source had no magnitude, the angular spaces represented by xx_1 and oo_1 (Fig. 8) would contain no light rays issuing from that source; but if for the electric light there be assumed a sphere 17 millimetres in diameter, there will be for least vertical divergence, namely, that at the highest or lowest zone of the refractor, $\frac{\delta}{2} = \tan^{-1}\left(\frac{8{\cdot}5}{873{\cdot}8}\right) = 0° 33'$, and δ or the whole divergence $= 1° 6'$. Thus these angular spaces are well supplied with light rays, but the curves shown will still serve to indicate the difference of mean inclination in passing from side to side of an element. Taking each pair of corresponding upper and lower zones of the same form many different combinations might be made. That which has been chosen in the design (Plate 16, Fig. 10) is represented in Table I. and Plate 16, Fig. 9.

TABLE I.

Number of Zone.	Maximum Difference of Inclination.	Lateral Vertical Section.		Middle Vertical Section.	
		Angle between outer limiting focal rays.	Angle between inner limiting focal rays.	Angle between outer limiting focal rays.	Angle between inner limiting focal rays.
	′	′	′	° ′	′
3	12	36	− 24	1 0	0
4	14	32	− 28	1 0	0
5	16	28	− 32	1 0	0
6	16	0	− 32	0 32	0
7	18	0	− 36	0 36	0
8	19	0	− 36	0 38	2
9	21	0	− 36	0 42	6
10	25	0	− 36	0 50	14
11	23	0	− 36	0 46	10

NOTE.—The second column is applicable to zones below as well as to zones above the focal plane; the third and fourth columns apply to the combined effects of each pair of corresponding upper and lower zones; divergent angles are considered positive, convergent negative.

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It will be seen from Plate 16, Fig. 9, that the combined effect of zones 3 to 11 above and below the focal plane will be to send out a pencil of light, with an amount of divergence in the vertical plane diminishing gradually from the maximum value of 1° in the middle to the value of 36′ at either lateral section. Taking the bounding lines for flash from zones 3 (Fig. 9) to represent this pencil of light, it is important to consider what appearance the light would present to a mariner on the sea. The lowest ray from a middle section dips 12′ below that from a lateral section, hence opposite a middle section the light will cease to be visible at a less distance from the tower than opposite a lateral section. If, indeed, the mariner place himself so as to receive the most dipping rays only, he will see a momentary flash each time the axis of a 15°-division of apparatus passes between him and the light source; if he gradually recede from the tower the duration of the flash will gradually increase until he arrives at the distance at which the lowest rays from a lateral section become visible, when the flash will have its full duration; this it will retain afterwards, until he passes beneath the horizon, and loses the light entirely. Although, if no other light than that from zones 3 to 11 of the refractor were sent out, a diminution of duration of flash would occur after passing the distance to which the highest rays from a lateral section carry, this effect will not actually occur, since it is proposed to send all the light from the catadioptric rings, as well as from two of the central zones of the refractor to the horizon. Further, the central zone, and that next below it, can be formed so as to light the sea up to the distance from the tower which may be deemed necessary, so that the first-mentioned effect would occur, if at all, only when the state of the atmosphere was such as to render the light from these zones invisible before that from the remainder of the apparatus. Even should this effect take place, it is not a dangerous one, since the interval from centre to centre of the flash, and the number of flashes occurring in a given time, remain unaltered.

If, on the other hand, the combined effect of the refracting zones were represented by the bounding lines of flash from zones 6 (Fig. 9), the mariner might possibly receive three short flashes instead of one flash from each 15°-division, the characteristic of the light thus being completely changed.

The consideration of these two effects has led to the adoption of the arrangement shown by Fig. 9,[1] with which arrangement the second effect cannot occur.

[1] See also Fig. 10, in which zones 3 to 11 above and below the focal plane are represented as acting together.

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Zone 1, if made as shown in continuous lines (Fig. 10), would direct the light it receives to the horizon; if made as shown by the dotted line as to inner curvature, it would spread its light over an angle of 4° 30′ from the horizon downwards.

Zone 2, above the focal plane, is calculated to send its light to the horizon.

Zone 2, below the focal plane, would spread the light it receives over an angle of 6° 30′ from the horizon downwards.

These three central zones have their outer faces cylindrical, and would send out the rays incident on them free from difference of inclination, at any level in the vertical plane, from side to side, and with uniform condensation in azimuth from top to bottom.

Fig. 10 shows in continuous lines a vertical section of the entire apparatus at the side of a 15°-division in azimuth; the dotted lines show the forms assumed by the profiles in a vertical section at the middle of a 15°-division. The refracting drum would be lowered, first, by 6 millimetres below the luminous focus, in order to send the highest emerging rays out at right angles to the vertical axis, and further by the amount necessary to send these rays to the horizon, due to the height of the apparatus above the sea level. The catadioptric rings above and below would be raised so as to make the mean inclination of the emergent rays that suited to lead them to the horizon. Supposing, then, the rate of revolution to be one turn in three minutes, and that the angle of 3° into which the focal rays are condensed is increased to 4° by ex-focal rays, the combined effect of the whole apparatus would be to give alternate light and dark periods, the former of two seconds', the latter of five-and-a-half seconds', duration, whilst the strongest light would be directed to the horizon, and light of less and less intensity to the sea surface nearer and nearer the tower.

Turning now to the general question, it will be interesting to find what amount of condensation in azimuth can be obtained without causing a material difference of inclination in the vertical plane of emerging rays from one side to another of a horizontal compartment.

The following Table shows seven examples of condensation greater than 1·5, and in each of these the lateral emerging rays from zone 11 above the focal plane dip below axial rays emerging at the same level.

In two examples of condensation less than 1·5, namely 1·3 and 1·2, the lateral rays rise above the axial.

Seven examples of a condensation of 1·5, embracing horizontal compartments varying in extent from 60° to 12°, are then given.

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If zone 11 be considered, it is seen that, for condensation of 24° into 16°, lateral rays dip 2′ below axial; that this angle of dip diminishes to 1′ 40″ for 36° into 24°; and, further, to — 2′, or an angle of 2′ rise for 60° into 40°; again, when one considers smaller compartments than 24°, it appears that the dipping angle of 2′ diminishes to 1′ for 20° into 13° 20′, to less than 1′ for 18° into 12°, to — 2 for 15° into 10°, and to — 0′ 30″ for 12° into 8°.

TABLE II.

Results of calculations made in search of the amount of azimuthal condensation that can be obtained by increasing the horizontal curvature of the outer face of sections of the Fresnel fixed light refractor, without appreciably altering the parallelism of emerging rays in the vertical plane, and proving that a condensation of 1½ can be so obtained.

Azimuthal condensation.	Difference of Inclination in the vertical plane between axial and lateral rays emerging at the same level.		Difference of Azimuthal deviation of highest and lowest emerging rays at the side of a horizontal compartment of any zone of the refractor.
	Zone 11 above the focal plane.	Top of central zone.	
° ′ ° ′	° ′ ″	° ′ ″	° ′
6 0 into 1 0, or 6·0	0 5 0 dip at sides	..	0 15
12 0 „ 2 0 „ 6·0	0 22 0 „ „	..	0 29
18 0 „ 6 0 „ 3·0	0 25 0 „ „	..	0 30
15 0 „ 6 30 „ 2·3	0 12 0 „ „	..	0 19
22 30 „ 11 15 „ 2·0	0 17 0 „ „	..	0 24
22 30 „ 14 30 „ 1·55	0 3 0 „ „	..	0 15
24 0 „ 15 0 „ 1·6	0 5 0 „ „	..	0 16
24 0 „ 18 0 „ 1·3	0 0 rise „	..	0 9
24 0 „ 20 0 „ 1·2	0 4 0 „ „	..	0 5
60 0 „ 40 0 „ 1·5	less than 0 2 0 „ „	less than 0 3 0 rise at sides	0 36
36 0 „ 24 0 „ 1·5	0 1 40 dip „	..	0 21
24 0 „ 16 0 „ 1·5	0 2 0 „ „	..	0 14
20 0 „ 13 20 „ 1·5	0 1 0 „ „	0 0 20 dip „	0 12
18 0 „ 12 0 „ 1·5	less than 0 1 0 „ „	0 2 10 rise „	0 11
15 0 „ 10 0 „ 1·5	0 2 0 rise „	..	0 9
12 0 „ 8 0 „ 1·5	0 0 30 „ „	0 0 2 „ „	0 7

A similar calculation made for the top of the central zone, in compartments of 60°, 20°, 18°, and 12°, shows that the difference

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of inclination between lateral and axial rays does not materially differ from that found for zone 11; for intermediate zones this difference passes through values intermediate to those for the highest and the central zone; hence, a condensation of 1·5 can be obtained without appreciable difference of inclination in the vertical plane of rays emerging at the same level.

In the fourth column of Table II. is given the difference of deviation in azimuth of the highest and lowest lateral emerging rays for any zone of the refractor; this difference increases with the extent of the compartment in azimuth, and also with the amount of condensation. In all the cases given, the uppermost lateral rays, which suffer less deviation than the lowest, have been directed to the limits of the angles lighted by the catadioptric zones, so that the waxing or waning angles of column four fall within the calculated light periods, and do not encroach on the periods of eclipse.

If, then, it be desired to have an apparatus which would emit rays free from difference of inclination in the vertical plane from side to side of each horizontal compartment, thus rendering it unnecessary to resort to the disposition given to the refractor in the design already described for condensation of 15° into 3°, Table II. shows that the amount of condensation cannot materially differ from 1·5, and the ratio between the light and dark periods thus being constant, whatever be the number of horizontal compartments given to the apparatus, it would appear advisable to choose that number, which, while not on the one hand necessitating more vertical settings than are needful to support the glasswork, would not, on the other hand, involve an inconvenient increase of thickness in the axial section. An apparatus of ten 36°-compartments may be recommended. Plate 16, Fig. 12*a* and Fig. 12*b*, represent this apparatus to the scale $\frac{1}{16}$. The light periods would be twice as long as the dark, and the intensity $1\frac{1}{2}$ time that of fixed white.

The foregoing deals with the effects obtainable by single agency; were double agency partially adopted, a useful apparatus giving a higher degree of condensation might be constructed. The form of catadioptric prism proposed is fitted to send out the light incident on it condensed precisely in horizontal and vertical planes, and this without restriction as to the amount of azimuthal condensation. If now a number of horizontal compartments, which when divided by 2 is odd (*e.g.*, 10, 14, 18, &c.) be taken, and a refractor and spherical mirror be placed alternately in these compartments, an intensity three times that of fixed white can be

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obtained (neglecting loss due to absorption in the mirror); for, instead of putting 20° into 13° 20′, for example, 40° may thus be put into 13° 20′. Then, for the catadioptric zones, 40° can at once be condensed into 13° 20′. Thus an apparatus of eighteen horizontal compartments for the drum, and of nine compartments for the cupola and lower reflecting prisms, is obtained.

In an Appendix will be found all the steps of the calculation required to test the inclination of emerging rays in horizontal and vertical planes for a condensation of 20° into 13° 20′. The difference of inclination in the vertical plane of the axial and lateral emerging rays, which is but 1′ for zone 11, diminishes to 0′ 20″ for the central zone; whilst in the horizontal plane only 12′ of waxing and waning have to be added to that due to the size of the electric spark.

Plate 16, Fig. 11*a* and Fig. 11*b* represent this apparatus to the scale of $\frac{1}{16}$.

An analysis of the elements of expenditure has been made for the particular case of an azimuthal condensation of 15° into 3°. The apparatus for obtaining this effect by single agency has been described; on the other hand, the profiles and dimensions of straight prisms, which in combination with the existing second order fixed light apparatus would give the same effect, have been determined. After consultation with Messrs. Barbier and Fenestre, the Author is authorised to state that comparison of the relative costs of a first apparatus of either kind is in favour of the latter method; but for subsequent apparatus, the cost of an apparatus condensing in azimuth without straight prisms would be less than one producing the same effect by the aid of straight prisms in the proportion of 3 to 4.

It remains for the Author to acknowledge the obligation under which he stands to the Messrs. Barbier and Fenestre, at whose works, and on the initiative, as well as with the advice and encouragement of the former of whom, the foregoing study has been made; he cannot fitly conclude without alluding to the unfailing kindness, frankness, and courtesy with which they have instructed him in regard to the practical appliances for the execution of the various forms of prism in use, and to the methods of testing the finished elements.

The Paper is accompanied by several diagrams, from which Plate 16 and the woodcuts in the Paper and Appendix have been prepared.

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APPENDIX.

Test of difference of inclination in the vertical plane of rays emerging at a given level, and of difference of deviation in azimuth between the extreme upper and lower emerging rays from a horizontal compartment, for a refractor condensing each 20° in azimuth into 13° 20′.

In the following example the eleventh zone above the focal place is considered.

Let $a\,b\,c\,e$ (Fig. α) represent the lateral vertical section of a zone of the refractor, the distance of b from the vertical focal axis is approximately 730 millimetres for all the zones of the drum from 2 to 11.

Hence, to ensure that all the rays emerging from the lateral section fall within the angle of 13° 20′ to be lighted, r_1 (Fig. β) must be taken at the inclination in azimuth to F b, suited to bend the ray F $c\,b$ (Fig. α) through 3° 20′ in azimuth. Hence (Fig. β)

$$\angle \mathrm{F}\,b_1\,\mathrm{C} = \tan^{-1}\frac{\sin 3^\circ\,20'}{1{\cdot}53 - \cos 3^\circ\,20'} = 6^\circ\,14'.$$

Hence d, or the distance between the focal vertical axis and the centre of horizontal curvature of outer face, which also determines the relative position of the prism to the vertical axis of the polishing table, is found from

$$d = 730\,\frac{\sin\ 6^\circ\,14'}{\sin 16^\circ\,14'} = 283{\cdot}54.$$

Now to find r, the radius of horizontal curvature at the level of a (Fig. α), draw (Fig. β) $a_1\,p$ at right angles to F C produced; then

$$a_1 p = 705 \sin 10^\circ = 122{\cdot}42$$

$$\mathrm{F}\,p = 705 \cos 10^\circ = 694{\cdot}29$$

therefore $$\mathrm{C}\,p = \mathrm{F}\,p - d = 410{\cdot}75$$

And $$\angle \mathrm{C}\,a_1\,p = \tan^{-1}\frac{\mathrm{C}\,p}{a\,p} = 73^\circ\,24'$$

but $$\angle \mathrm{F}\,a_1\,p = 80^\circ$$

$\therefore$ $$\angle \mathrm{F}\,a_1\,\mathrm{C} = 80^\circ - 73^\circ\,24 = 6^\circ\,36'.$$

Now for deviation in azimuth of ray, F $e\,a$ (Fig. α)

$$\sin^{-1}(\mu \sin 6^\circ\,36') - 6^\circ\,36' = 3^\circ\,32'.$$

Hence the ray F $e\,a$ after emergence falls within the limit of the angle lighted to the extent of 3° 32′ − 3° 20′, or 0° 12′.

Again $$r = 705\,\frac{\sin 10^\circ}{\sin 16^\circ\,36'} = 428{\cdot}52.$$

Let t be the axial increase of thickness of the prism at the level of a, then

$$t = d + r - 705 = 712{\cdot}06 - 705 = 7{\cdot}06.$$

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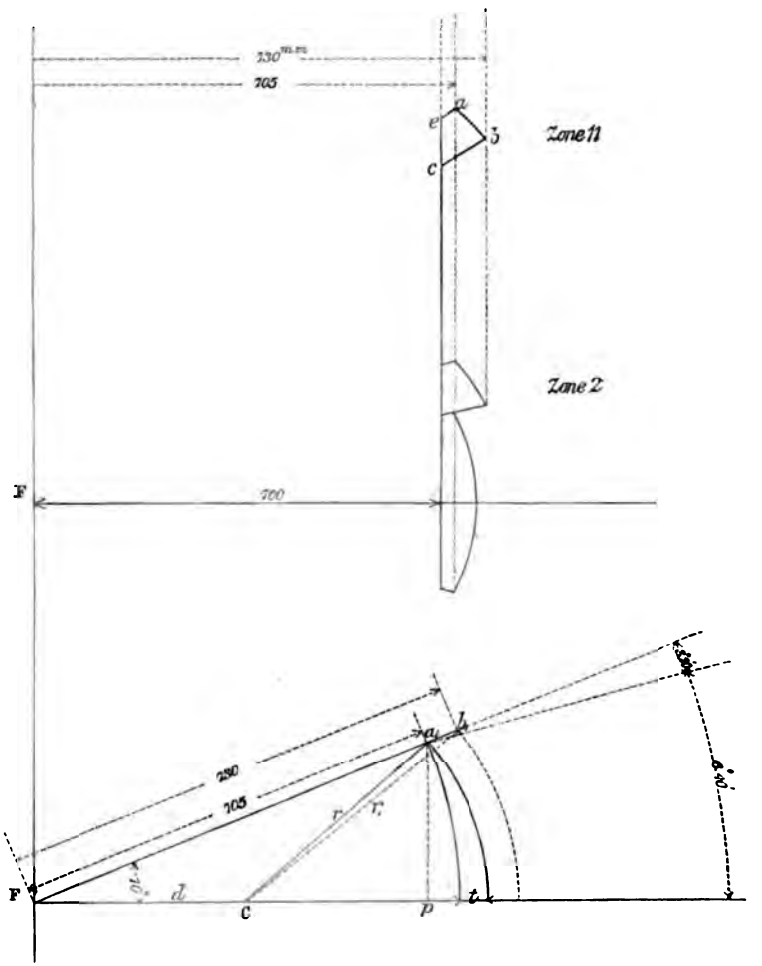
The height of e (Fig. α), the inside of the upper joint of zone 11, above the focal plane, is 523 millimetres;

hence the angle of incidence at $e = \tan^{-1} \frac{523}{700} = 36° 46'$;

and the angle of refraction at $e = \sin^{-1} \left(\frac{\sin 36° 46'}{\mu} \right) = 23° 2'$.

FIG. α and β.



A horizontal thickness of 5 millimetres being allowed for the upper lateral joints of all the refracting zones, the height of a above the focal plane is

$$523 + 5 \tan 23° 2' = 525 \cdot 125.$$

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Now calling I′ and R′ the angles of incidence and refraction of a ray which reaches the outer face of zone 11 in the axial section of a 20°-compartment at the level of a, it is found by the equation $700 \tan \{\sin^{-1}(\mu \sin R')\} + 12{\cdot}06 \tan R' = 525{\cdot}125$, that

$$R' = 22° 56\tfrac{1}{2}', \text{ and that } I' = 36° 36\tfrac{1}{2}'.$$

Let y denote the angle of internal incidence of this ray, in order that it may issue horizontally, then

$$y = \tan^{-1} \frac{\sin 22° 56\tfrac{1}{2}'}{1{\cdot}53 - \cos 22° 56\tfrac{1}{2}'} = 32° 36' 54''.$$

Let α_m denote the inclination to the horizon of the radius of vertical curvature of the outer face at the middle of a compartment, when this radius, if produced, would emerge from the prism at the level of a, and let α_e denote the inclination of the radius for point a; then

$$\alpha_m = y + R' = 55° 33' 30'',$$

and

$$\alpha_e = \tan^{-1}\{\tan \alpha_m \sec 6° 36'\} = 55° 44' 8'';$$

again, the angle of internal incidence for ray $F\,e\,a$

$$= \alpha_e - 23° 2' = 32° 42' 8''$$

and the angle of emergence for the same ray

$$= \sin^{-1}(\mu \sin 32° 42' 8'') = 55° 45' 8'',$$

and taking the difference between this angle and α_e it will be seen that the lateral ray $F\,e\,a$ dips by an angle differing little from 0° 1′ below the horizon, and therefore also below the axial emerging ray at the same level.

Next let the difference of inclination in the vertical plane between a middle and lateral ray emerging from the top of the central zone of the drum, the former emerging at the same level as the latter, be determined. 127 being the internal height of this zone above the focal plane, the first angle of incidence of the highest ray

$$= \tan^{-1} \frac{127}{700} = 10° 17',$$

and the first angle of refraction $= \sin^{-1}\left(\frac{\sin 10° 17'}{\mu}\right) = 6° 42'.$

The highest level of the lateral joint is

$$127 + 5 \tan 6° 42' = 127{\cdot}587$$

Hence I′ and R′ being angles of incidence and refraction for the ray emerging from the middle of a compartment at this level:

$$700 \tan \{\sin^{-1}(\mu \sin R')\} + 12{\cdot}06 \tan R' = 127{\cdot}587;$$

hence

$$R' = 6° 39' 40'', \text{ and } I' = 10° 13' 20'';$$

hence y being the angle of incidence previous to emergence, in order that this ray may issue horizontally,

$$y = \tan^{-1}\left(\frac{\sin 6° 39' 40''}{1{\cdot}53 - \cos 6° 39' 40''}\right) = 12° 11' 33''.$$

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Then α_m and α_s being the inclination to the horizon of the radii at the middle and lateral sections respectively, and for level 127·587,

$$\alpha_m = \gamma + R' = 18° 51' 13'';$$

and $$\alpha_s = \tan^{-1}(\tan \alpha_m \sec 6° 36') = 18° 58' 13'';$$

further the angle of emergence of the lateral ray

$$= \sin^{-1}(\mu \sin \overline{\alpha_s - 6° 42'}) = 18° 58' 33'',$$

and subtracting from this angle the angle α_s, it is seen that the lateral ray dips 0° 0′ 20″ below the horizon, and below the axial emerging ray at the same level.

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(*Students' Paper, No. 157.*)

"Description of a Composite Screw Tug-Boat."[1]

By JOHN AUGUSTUS THOMPSON, Stud. Inst. C.E.

IN the month of March 1881 the Author had entrusted to him the preparation of the specification and drawings for, and the superintendence of the construction throughout of a Composite Screw Tug-Boat, of 65 tons gross register and 150 IHP., for service at the Cape of Good Hope. This boat was to class not less than 16 A1 at Lloyd's, to attain a speed of 10 knots an hour in station rig, and to be constructed to withstand heavy seas; also to be fitted aft with a patent platform and appliances for launching anchors over the stern.

The dimensions and principal particulars of the vessel are:—

	Feet. Ins.
Length between perpendiculars	70 0
„ over all	73 0
Breadth outside planking	16 0
Depth of hold	8 6
Draught of water loaded, about	7 0
	Tons.
Displacement at 7 feet 2 inches draught	112
Displacement per inch at load-water line	2
Coefficient of displacement	0·59
	Square Feet.
Area of midship section	88·33
Coefficient of midship section	0·92
	Feet.
Centre of displacement (from stem)	33·93

The weights are:—

	Tons.
Hull, wood and iron	36
Engines	10
Shafting and propeller	1
Boiler and water	20
Cabins, masts, sails, rigging, &c.	8
Coals	14
Bolts, nails, cement, &c.	8
Water and tanks	3
Sheathing and nails	2
Making a total of	102

[1] This communication was read and discussed at a Meeting of the Students on the 31st of March, 1882, and has been awarded a Miller Prize.

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The vessel was built by Messrs. Green of Blackwall, was engined by Messrs. Wilson and Co. of Vauxhall, and was named the "James Searle."

The scantlings, etc., are as under:—

Keel of elm, 11 inches by 9½ inches; false keel of elm, 3 inches thick; keel-plate of iron, 19 inches wide by ½ inch thick; frames, 3 inches by 2½ inches by $\frac{5}{16}$ inch spaced 18 inches apart throughout; reverse frames, 2¼ inches by 2¼ inches by ¼ inch to the bilge and gunwale alternately; floors, 10½ inches by $\frac{5}{16}$ inch to the upper turn of the bilge cemented throughout as well as all framework; deck beams, 4 inches by 3 inches by ⅜ inch of angle-iron, riveted to alternate frames by a 12-inches by $\frac{5}{16}$-inch knee-plate; rounding up of beams, 4½ inches; hold stanchions on alternate frames, 2 inches in diameter; waterway stringer-plate, 10 inches by $\frac{5}{16}$ inch secured to the sheer-strake plate by an outside angle-iron 3 inches by 2 inches by $\frac{5}{16}$ inch, which houses the top plank and carries the caulking. The main keelson consists of a plate, secured on the top of the reverse bars, 10½ inches wide by $\frac{5}{16}$ inch, on to which were riveted two angle-irons, 3 inches by 3 inches by $\frac{5}{16}$ inch, enclosing a vertical web-plate 7 inches by ½ inch, fastened at its upper edge by two angle-irons, 3 inches by 3 inches by $\frac{5}{16}$ inch, riveted to a 6½-inch by $\frac{5}{16}$-inch plate. This keelson for the space occupied by the engines and boiler was stopped off, and two side keelsons of more than equivalent strength were substituted, allowing the engines and boiler to be placed so that the weights should be kept as low as possible. The bilge-stringer consists of two angle-irons back to back, 3 inches by 3 inches by $\frac{5}{16}$ inch, riveted on to the top of the reverse bars. An outside bilge-plate 8 inches by $\frac{5}{16}$ inch ties the frames together at the height of the termination of the floor-plates. There is a longitudinal stringer on the side between the deck and the bilge-stringer of two angle-irons 3 inches by 3 inches by $\frac{5}{16}$ inch. The sheer-strake stringer-plate, 12 inches wide by $\frac{5}{16}$ inch thick, is riveted to the frames and waterway stringer-plate.

The boat is planked with elm 3½ inches thick from the keel up to within 1 foot below the draught water-line; above that the planks are of teak 3½ inches thick, the four upper strakes gradually diminishing to 2½ inches in thickness. The deck is of teak 2¼ inches thick; the covering board is also of teak 2¾ inches thick. The bulwarks are of pine, 24 inches high, with rough tree rail of teak 6 inches by 2½ inches, and having stanchions of teak stepped into cast-iron sockets.

The vessel is provided with yellow metal fastenings, and is

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sheathed with 24, 26, and 28-oz. metal up to 8 feet 3 inches forward, and 8 feet aft.

The hull is close-ceiled with 1½-inch pine. There is one collision bulkhead right forward, one bulkhead forward of the boiler, another aft of the engines, and one aft collision bulkhead. These bulkheads are of ¼-inch plate, stiffened with angle-irons, 2 inches by 2 inches, spaced 24 inches apart, and are fitted with sluices and rods to the deck.

The coal bunkers have a total capacity for 14 tons, and are fitted on each side of the boiler, being constructed of ⅛-inch iron stiffened by 1½-inch by 1½-inch angle-irons. The coamings to the engine and boiler hatches are of iron 2 feet high, and the engine-room skylight is made of teak fitted with shutters and circular lights.

A full equipment of ground tackle of extra strength has been provided, on account of the heavy weather which the vessel may sometimes have to encounter. The crew numbers nine hands all told, and the vessel was schooner-rigged for the voyage out, having spars of best Norway pine, the standing rigging being of wire rope.

The machinery consists of a pair of compound inverted direct-acting surface-condensing engines. The chief novelty about them consists in their being fitted with Mr. David Joy's valve-gear in lieu of link-motion, and with Messrs. Paynton and Wilson's slide-valves instead of the common slides. The Author believes these are the first marine engines with the two combinations that have been made on the Thames, and the result has proved most satisfactory. There is no receiver to this engine beyond that formed by the spaces outside the high-pressure slide-valve (as will be seen on the sectional plan of the cylinders), the exhaust passage to the low-pressure slide, and the interior of the low-pressure slide-valve, amounting together to 3,594 cubic inches; the capacity of the high-pressure cylinder, one passage and one clearance, is 3,419 cubic inches.

The principal sizes of the engines are:—

The diameters of the cylinders are 15 inches and 27 inches, giving a ratio of 1 to 3·24 in their areas, the length of stroke being 18 inches. The crank shaft, forged of best scrap iron, is 5 inches in diameter in the journals. The main brasses consist of fore and aft brasses 8 inches long each, and a centre brass 12 inches long, having a total surface of 140 square inches. The connecting-rods are 3 feet 9 inches from centre to centre, being equal to five cranks. The piston-rods are carried through the top covers as well as the bottom, so as to support the weight of the pistons when the vessel is rolling heavily.

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The surface condenser was made large on account of the climate where the boat had to work, viz., 450 square feet, or 3 square feet per IHP. The air-pump is 10 inches in diameter by 9½ inches length of stroke, and is single-acting. The circulating-pump, 4½ inches in diameter by 9½ inches length of stroke, is double acting. These two pumps are wrought by levers from gudgeons on the piston-rod heads, and are fitted with metallic valves. The feed- and bilge-pumps are 2 inches bore, driven off the air and circulating-pump crossheads, and were bored for their entire length, the rams, glands, valves, and neckbushes being of gun-metal.

The stern-tube and propeller are of gun-metal, the latter being 6 feet in diameter, with three blades, and a mean pitch of 10 feet 6 inches. The engine-room outfit is large, a spare propeller and tail-end shaft being included amongst the spare gear.

The boiler is of the ordinary marine return-tubular type of circular form, having two furnaces and two combustion chambers, with a total heating surface of 700 square feet, the working pressure being 70 lbs. per square inch. The diameter of the shell is 8 feet 7½ inches internally, its length is 9 feet, and the diameter of the furnaces is 2 feet 6 inches outside. The shell-plating is double riveted longitudinally with rivets in double shear; it is ⅝ inch thick, of best best Belmont iron. The tube-plates are of Farnley iron ⅝ inch thick. The furnaces are also of Farnley iron, the upper half $\frac{1}{3}\frac{3}{2}$ inch, and the lower half $\frac{7}{16}$ inch thick. The end plate is best Belmont iron ⅝ inch thick. All screwed stays are fitted with nuts, and the fore and aft stays have nuts and washers inside and outside, and the steam-space plating at the smoke-box end is protected from the heat. There are one hundred and ten iron tubes of 3 inches outside diameter and 6 feet 6 inches long between the tube-plates.

This boat was taken down to run the measured mile on the 8th of September, 1881, and was put five times up and down the course. The mean result of these runs was a speed of 9½ knots per hour, the vessel being at the time rigged for the voyage out.

The steam-pressure was 70 lbs. per square inch, vacuum 27½ inches, and revolutions per minute one hundred and thirty-two, at which the engines developed 170 HP. The slip of the screw, as indicated by the revolutions made by the engines against the resulting speed of the boat, came out as high as 30 per cent.; but this fell off considerably when the speed of the boat was slightly reduced, and could only be accounted for by being brought about through the great width of the wooden stern-post, which at a high speed caused much broken water for the propeller to work in.

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The log-book of the voyage to the Cape shows that the vessel was fifty-four days under steam; but during only forty-six days is there any record of the patent log having been overboard. In this time 5,953 miles were traversed, or an average of 130 miles per day; the speed varied from 172 miles down to 29 miles per day, the latter days' work being due to the very heavy weather encountered on the run out; the former speed was once only attained, and that on a fine day. The principal part of the voyage was made under very trying weather. The average consumption of fuel was about 25 cwt. of coal per day, which is equivalent to 117 lbs. per hour. As the boat travelled 11 miles or 9·5 knots per hour on the trial, during which the engines developed, as shown by the indicator, 170 HP., and as the highest speed of the boat at sea during the finest weather by the patent log was 7·2 knots per hour, the relative HP. required for the latter speed would certainly be not less than 85. The draught of water on the day of the trial was less than when the vessel was fully equipped with stores, &c., for the voyage out. Taking the HP. developed as low as 85 on the run out, the consumption of fuel is very light indeed, namely, 1·37 lb. per hour per IHP. The Author is of opinion that this economical result is attributable to the uniform distribution of steam at any desired cut-off, as attainable by Mr. Joy's valve-gear, the free exhaust allowed by Messrs. Wilson's valves and the small power absorbed in working the same, and the long connecting-rods employed.

It will be noticed, in the high-pressure expansion diagram taken by the Author on the trial trip, that the steam-pressure in the cylinder is as high whether the engine is in full gear or linked up to dead slow; and the result as to absence of extra back-pressure is just as conspicuous; these are two most important points gained in the working of steam expansively. Diagrams Nos. 1 and 2 are intended to show the strains passing through the piston and connecting-rods, the thrust on the guides, the shearing effect on the crank-pin, and the turning effect on the same respectively of the high- and low-pressure engines. Diagram No. 3 represents the combined crank-pin turning effects transmitted through the after journal, the cranks being at right angles, and the low-pressure crank leading. These diagrams were devised and computed by the Author from the indicator cards taken by himself when the engines were tried under steam. It will be noted that there are both dotted and full lines in these diagrams. The full lines were first computed upon the wrong impression that the connecting-rods were 3 feet 5 inches from centre to centre,

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whereas they are 3 feet 9 inches, and the relative strains as referred to the 3 feet 9 inches rods are shown in dotted lines.

The maximum strains that come into play during one revolution are:—

	High-pressure Engine.	Low-pressure Engine.
	Tons.	Tons.
Thrust on piston-rod	4·08	5·10
„ „ guides	0·75	0·85
„ „ connecting-rod	4·10	5·12
Shearing effect on crank-pin	3·80	4·20
Turning	3·61	4·15

The minimum strains are simply those due to momentum of parts.

The maximum combined torsional effects which pass through the after journal, as shown on Diagram No. 3, amount to a maximum of 6·2 tons, and a minimum of 3·35 tons on a 9-inch lever, the former taking place as the high-pressure crank-pin completes 300° of its path, its piston being on the up-stroke; whilst the low-pressure crank-pin has completed 30°, its piston being on the down-stroke; the smaller stress takes place when the low-pressure crank-pin is on the top centre, and the high-pressure crank-pin is 90° behind it.

The Paper is accompanied by several drawings and diagrams, from which Plate 17 has been prepared.

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OBITUARY NOTICES.

MR. JAMES BLACKBURN was born at Halifax on the 24th of October, 1835. His father, Mr. Joshua Blackburn, was connected with the dyeing trade of Yorkshire, and the son was early employed in the same business. The knowledge of chemistry then acquired was of the utmost value to him in the profession of gas engineer which he subsequently adopted. Mr. Blackburn afterwards spent some time in a lawyer's office at Wakefield. Whilst there he continued to pursue his studies in chemistry, being a pupil of the Rev. Dr. Bowditch. He then served a pupilage of three years under Mr. S. P. Leather, Engineer of the Gas Works at Burnley, and received instruction in hydraulic and gas engineering. At the age of twenty-three he married, and shortly afterwards obtained the appointment of Engineer and Manager of the Gas Works at Droylsden, a suburb of Manchester. There he remained for seven and a-half years, or from March 1861 to December 1868, during which time he entirely reconstructed and greatly improved the works, and acted also as consulting engineer for several smaller works in the neighbourhood. Besides attending closely to his duties at the gas works, he became a Director, and afterwards Secretary, of the Droylsden Educational Institute. He was also a member of the Council of the Union of Lancashire and Cheshire Institutes. In the earlier years of the work of the Science and Art Department, Mr. Blackburn organised the Science Classes at the Institute in connection therewith, devoting his spare hours largely to this labour. Many of the youths of the neighbourhood who have now attained to manhood, and are occupying prominent and responsible positions in places widely apart, are ready to testify that much of their success in life has been due to what Mr. Blackburn accomplished for their welfare and advancement.

But it will be for his labours in connection with the "British Association of Gas Managers," now the "Gas Institute," that the name of Mr. Blackburn will be best remembered and esteemed. Prior to the formation of that Association, the position of the gas managers and engineers of this country was one of comparative isolation. Gas-making, to a large extent, was looked upon as a close science; and many of those who had the control of the establishments in the various towns of the kingdom were too much

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in the habit of exercising a jealous regard to keep the processes adopted at their respective works, with the working results, strictly secret, even from other members of the same profession. This state of things was deemed undesirable by many thoughtful gas engineers; and it was felt that a means of personal contact, and the meeting together of practical men for the discussion of matters appertaining to gas manufacture, were both essential and necessary. In due time, the Association was established on lines similar to those of the "North British Association," in Scotland. Mr. Blackburn entered heartily into the project. The initiatory meetings were held at Manchester, and on the Committee being appointed, Mr. T. Hawksley, Past-President Inst. C.E. was unanimously elected the first President, and Mr. James Blackburn, the Honorary Secretary. The Association was fortunate in its secretary. He possessed a nice balance of qualities that fitted him for the post; his power of organisation had full scope, and he exercised it in a way which elicited the admiration of his colleagues and of the members who joined in yearly increasing numbers. His untiring energy and resource, his habits of order and method, combined with a rare courtesy and kindliness of disposition, were conspicuous at the yearly meetings, and in the general conduct of the Association, not less than in the growing correspondence which it entailed upon him.

It was natural that Mr. Blackburn's talents should obtain recognition outside the sphere of these labours; and, accordingly, he was selected in 1868 by the Directors of the Oriental Gas Company, as engineer and manager of their works at Calcutta and Howrah. Prior to leaving England, the members of the British Association of Gas Managers presented him with an extensively signed address, a purse of gold, and a valuable microscope. The same diligence and devotion to duty as at home characterised his work in the capital of India. During his *régime* he entirely remodelled the works, and enlarged them to the capacity of delivering 1,000,000 cubic feet of gas per day. The negotiations with the municipality, especially in the renewal of the Company's concession, were conducted by him with marked discretion and ability, which obtained suitable recognition from his employers. He was held in high repute at Calcutta, was consulted on many important engineering questions outside his own immediate duties, and was appointed an honorary magistrate. In the course of a visit to England, in 1874, he was elected an honorary member of the British Association of Gas Managers.

Mr. Blackburn's health during the thirteen years of his residence

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at Calcutta was generally good, though during the latter part of his career he occasionally experienced symptoms of liver complaint. He was loath, however, to relinquish the work to which he was so ardently devoted in India. On the 7th of January of the present year he was attacked by fever and inflammation of the liver; on his recovering sufficiently to be able to travel, he was ordered by his medical adviser to return to England, and whilst there to take absolute rest of body and mind. On his arrival he sought the needed quiet and mental repose at Weston-super-Mare. At first he seemed to improve, and he began to entertain pleasing anticipations of resuming his duties in restored health after a few months' sojourn; but the disease from which he suffered gradually undermined his strength, and he died on the 23rd of May, 1882, in the forty-seventh year of his age, leaving a widow and three sons to mourn his loss.

Mr. Blackburn was elected an Associate on the 4th of December, 1866, and was transferred to the class of Members on the 22nd of December, 1874.

Mr. JOHN ENGLAND, who was born on the 6th of March, 1813, was the third son of Mr. Thomas England, of Lloyd's, underwriter. He was apprenticed on the 3rd of January, 1828, to the late Mr. Bryan Donkin, and never failed to appreciate the peculiar advantage of this preliminary mechanical training, as forming the best entrance to the engineering profession. Before the termination of his apprenticeship he was sent by Mr. Donkin to Italy, to erect some millwork, which he did much to the satisfaction of the proprietors. Subsequently he became engaged, under the late Mr. I. K. Brunel, V.P. Inst. C.E., as a Resident Engineer during the construction of the Bristol and Exeter Railway, and there he remained for seven years. Mr. Brunel, writing of him many years afterwards, said: "I have, from my own knowledge of him, as well as from the report of others, a very high opinion of his abilities and of his general acquaintance with engineering in all its branches, including particularly a knowledge of machinery and millwork not generally possessed by engineers." He was employed for the ensuing four years, chiefly under the late Mr. Robert Stephenson, M.P., Past-President Inst. C.E., in responsible positions connected with engineering works. One of these was the survey for a proposed railway from Christiania to Mjösen, which he carried out in such a manner as to elicit

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a high encomium from the Royal (Norwegian) Commissioners, who commended his indefatigable activity and great ability. Financial considerations delaying the construction of this line, Mr. England was in 1840 selected to set out a railway from Lima to Callao. He thus entered upon a work which bid fair at the time to be the beginning of a prosperous career of professional achievement and advancement, but which, in consequence of a complete failure of health, was doomed to prove not only a disastrous check then but an insuperable obstacle to success thereafter. From the outset the demands upon his constitution were severe. In a letter written in June 1849, he said that he had crossed the Isthmus to Panama, "where, in spite of being exposed to the scorching sun by day and to the heavy dews by night (sleeping in an open canoe for two nights on the River Chagres) I arrived, thank God, safe and sound. . . . The crossing by land from Gorgona to Panama, during the high tide of the Californian fever, was an event never to be eradicated from one's memory. All my heavy baggage, weighing 150 lbs. each package, was carried over a distance of 30 miles on men's backs; the horses were worn to skeletons; the one I rode broke down with me, and I was compelled to tramp the last 10 miles with the thermometer at 90° in the shade. The road, through a wild and thickly-wooded country, with here and there peeps of our park scenery, heightened by all the luxuriance of tropical vegetation, and curiously channelled out at all the rises and falls in numberless mule-tracks, was rendered almost insupportable by the carcases of dead horses in various stages of decomposition. Where they drop there they lie, and the only remedy is provided by Providence in the shape of hosts of carrion birds." Arrived at Lima, he soon discovered that merely to survey even a short line in Peru was a task of no ordinary difficulty, under a fierce sun, with an amount of open and covert resistance as obstinate as it was bigoted. Thus, although supported heartily by the President of the Republic, his duties, without efficient aid or assistance, proved more than his strength could endure. Falling into an utterly prostrate condition, the President had the kindness to offer the use of the steam-frigate "El Rimac," in order that by a sea voyage his health, broken down by over-exertion in the heat of the sun, might be re-established. His case was, however, regarded as almost hopeless. He was carried back across the Isthmus in a litter on men's shoulders, and embarked for home with apparently but faint prospect of surviving the voyage. A mere skeleton when he arrived, his recovery was exceedingly slow; and he never afterwards resumed the exercise of the profession. That he deeply felt

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this abrupt termination to a promising career there can be no doubt; but, with shattered health and exceedingly narrow means, he lived a life of dignified and patient frugality. He resided much abroad, and possessed a thorough knowledge of the languages, and familiarity with the literature, of Germany, of France, and of Spain, and has left behind him friends in every country that he visited.

Mr. England was elected a Member of the Institution on the 7th of March, 1848. In 1865 he contributed to the Institution a Paper on "Giffard's Injector."[1] In that communication he submitted, in an elaborate and exhaustive form, the opinions entertained at the time by French engineers and men of science respecting the theory of the action of the injector. This Paper (together with the lengthy discussion that followed) threw much light upon the mode of action of an appliance which had at first been thought to contravene the laws of hydro-dynamics, and helped to remove the mystery which had previously enveloped it. For this communication he was awarded a Telford Premium.

During the last three or four years of his life those charming social qualities and that good humour and sympathetic intelligence which had rendered him a favourite and a welcome guest everywhere, entirely deserted him; he sank into a condition of the profoundest hypochondriasis from which he never rallied, and on the 8th of February, 1882, he expired from sheer vital exhaustion.

MR. JOHN FRASER—the eldest son of Mr. James Fraser, architect, of Manchester—was born on the 28th of July, 1819, at Linlithgow, Scotland, where his father was engaged in the construction of extensive docks and other works at Charlestown, on the Frith of Forth, for the Earl of Elgin. He was articled to the late Mr. G. W. Buck, M. Inst. C.E.; and in 1842, on the completion of his pupilage, was appointed by Mr. Edward Woods, V.P., Inst. C.E., to take charge, as resident engineer, of the construction of the Salford Junction Railways, the Act for which was obtained by the Liverpool and Manchester Railway Company, for the purpose of effecting a connection with the Leeds and Manchester Railway; and under his immediate direction all the designs for the viaducts and bridges, including the cast-iron arched bridge over the River Irwell, were prepared. In 1846 Mr. Fraser left Manchester for

[1] Minutes of Proceedings Inst. C.E., vol., xxiv., p. 198.

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Yorkshire, having been appointed resident engineer under Mr. (now Sir John) Hawkshaw, Past President Inst. C.E., who was the engineer-in-chief, on the West Riding Junction and the Huddersfield and Sheffield Railways. In 1851–2 Mr. Fraser, still under Mr. Hawkshaw, who about this time left Yorkshire to take up his residence in London, became sub-engineer to the Leeds, Bradford, and Halifax Railway; and, on the establishment of an independent company for the construction of a line from Leeds to Wakefield, he was again appointed sub-engineer, and these lines, together with the Gildersome and Ardsley branches, were completed by him under Mr. Hawkshaw. Subsequently, the Methley Branch, 6 miles, the Ossett Branch, Ossett and Batley, and the Extension to Adwalton, 9 miles in length, were designed and carried out by Mr. Fraser, as engineer-in-chief.

In 1862 an Act was obtained for the construction of the West Riding and Grimsby Railway, a line 28½ miles in length, running between Wakefield, Barnby Don, and Doncaster, and now forming part of the Great Northern Company's main line to London. Mr. Fraser, and Mr. John Fowler, Past President Inst. C.E., were the joint engineers, but the works were more particularly carried out under Mr. Fraser's personal supervision. He had charge of the parliamentary work of the above lines, and during these transactions there were many Parliamentary conflicts with the powerful companies which surround the West Riding district, and who generally opposed the making of new lines. When the amalgamation took place between the various local lines before-mentioned and the Great Northern Railway, Mr. Fraser was appointed by the latter Company as engineer, and in that capacity he constructed the following railways:—in 1864, a branch to the Lancashire and Yorkshire Railway, at Bradford, 1 mile in length; in 1865–66, the Halifax and Ovenden Junction Railway, 3 miles in length, for the Lancashire and Yorkshire and Great Northern Railway Companies; in 1866, the Bradford, Eccleshill, and Idle Railway, and extensions, 4¼ miles; in 1867, the Idle and Shipley Railway, 2½ miles; in 1871–2, the Ossett and Dewsbury Railway, 2½ miles, and the Batley and Dewsbury, 1¼ mile; in 1871, the Pudsey Railway, 2¼ miles, and the Bradford and Thornton Railway, 7¼ miles; in 1873, the Halifax, Thornton, and Keighley Railway, 10 miles, and an extension of the last-named line from Thornton to Keighley, about 7 miles in length; but this was only partially completed at the time of his death. In 1870–1, he designed and built the North Bridge across the Hebble Valley for the Corporation of Halifax, an iron structure 60 feet in width, and

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having two spans of 160 feet each. Mr. Fraser was also the engineer of extensive railway schemes in Leicestershire and the Midland counties, beginning at Newark and running through Melton Mowbray to Market Harborough, with a branch from Tilton to Leicester over 50 miles in length. The construction of these lines was nearly complete before his death, and at the time that event occurred he had under consideration further extensions of these lines, so as to complete the southern outlet of this new system. He was well known in the Parliamentary Committee Rooms, where he had had a long and varied experience for upwards of five-and-thirty years. As an engineer he was deservedly held in high esteem for his professional ability. He died suddenly on the 24th of September, 1881, at his residence, Grove House, Headingley, Leeds, in the sixty-third year of his age. He became a Member of the Institution in March 1863.

Mr. ANTHONY HENRY KESSNER was born at Okrisko, Moravia, on the 27th of February, 1842, his father, Mr. Henry Kessner, being a forester. He was under education at the Polytechnicum at Vienna from 1860–63, passed the various examinations with distinction, and received the degree of Civil Engineer. In the next three years he was an assistant engineer on the Austrian State Railways, engaged in preparing the plans for, and in the execution of, the Transylvania Railway. After spending a year in France, he became an assistant to the late Mr. Edward Wilson, M. Inst. C.E., and was employed as an assistant engineer in the office, in the field, and on works of construction in Wales and on the Bristol and Portishead Railway. Between 1866 and 1868 he was a division engineer on the Union Pacific Railroad, in sole responsible charge of the locating, design, and execution of the Utah section, 72 miles in length. When this line was finished he returned to Vienna, and in January 1869 he commenced to practice as a Civil Engineer on his own account, and carried out, among other works, the Wien bridge, the Carlstadt-Fiume Railway (77 German miles), the Lemberg-Munkács Railway and its branches (34 German miles), &c. He was also appointed consulting engineer for the "Allgemeine Oesterreichische" Bank. On the dissolution of this bank Mr. Kessner lost his position, and, notwithstanding his abilities and varied engineering experience, he was unable to find employment in his native

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country. Although granted the rank of Civil Engineer, this bare distinction afforded no means of sustenance. In May 1878 he was appointed by "The Brazilian Imperial Central Bahia Railway Company, Limited," chief engineer and general manager of their line. Notwithstanding that a post of this nature, in a climate like that of Brazil, would expose his health and even his life to the greatest danger, his circumstances were such that he was glad to accept the post. At Bahia he distinguished himself by his activity and energy, and became gradually, though not easily, acclimatised. But, upon returning from a long and arduous railway journey, he was taken suddenly unwell, and, after only one day's illness, he expired on the 16th of May, 1881, at St. Felix, a short distance from Bahia, where he was buried, in the presence of about fifty persons, whose friendship and esteem he had acquired. His death was attributed to yellow fever, but, according to the report of the Austrian Consul, it really resulted from heart disease.

Mr. Kessner was elected an Associate of the Institution on the 12th of January, 1869, and he became a Member by transfer on the 6th of May, 1873.

Mr. STEPHEN WILLIAM LEACH, son of Mr. Stephen Leach, engineer to the Navigation Committee of the Corporation of London, was born at Turnham Green, Chiswick, on the 29th of October, 1818. He was educated at Kingswood, near Bristol, and at Ockbrook, near Derby. At the age of sixteen he left school and entered the office of his father. When his father's death occurred in 1841, he was appointed to succeed to the vacancy. In 1849 he became engineer to the Port of London, by appointment of the Corporation. In 1857, on the passing of the Act of Parliament by which the Conservancy of the River Thames was transferred from the Corporation of London to the present Board of Conservators, he remained in office as engineer to that body. In 1866 an Act was passed extending the jurisdiction of the Conservators, which up till that period had terminated at Staines, as far as Cricklade, in Gloucestershire. Mr. Leach then took charge of the river for its entire length, and continued in the active exercise of the numerous and responsible duties which thus devolved upon him till within a few weeks of his death.

Mr. Leach executed several important works for the improve-

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ment of the navigation of the River Thames; notably the new lock and weir at Teddington, the new locks at Egham, Windsor, Cleeve, and Benson, and the new weirs at Bellweir, Old Windsor, and Marsh. In addition, he rebuilt a large number of the works which, under the old Navigation Commissioners, had been allowed to fall into the last stage of dilapidation. The Conservancy fund not being available for the purpose, Mr. Leach was unable to carry out the much-needed works for relieving the valley of the Thames from the effects of the periodical floods to which it is subject; but he did what was possible with the limited means at his disposal, and in designing a new work he took especial care that it should be constructed so as to form a useful part of the comprehensive drainage scheme which he foresaw would some day have to be undertaken. The numerous reports in which he dealt with this subject show the interest he took in it. The report relating to the drainage of the Oxford district he drew up in conjunction with his old and valued friend, the late Mr. Nathaniel Beardmore, M. Inst. C.E. Whilst always ready to place the results of his large and varied experience at the disposal of any one who applied to him for information or advice, the great demands on his time made by his official duties prevented him from undertaking any private practice, with the exception of the three landing stages at the Metropolitan Cattle Market at Deptford, and some other works which he carried out for the Corporation of London. He was also entrusted by the Corporation with the duty of periodically inspecting and reporting on the foundations of London, Southwark, and Blackfriars bridges.

Mr. Leach occupied a prominent position in his native place, Chiswick, and took an active part in all local matters. He personally assisted at the Sunday Schools at Turnham Green, and was treasurer for the Charity Schools at Chiswick and Strand-on-the-Green prior to the formation of the School Board in November 1872, of which he was the Chairman until his death. He was also treasurer of the Burial Board, and one of the Improvement Commissioners; and in the latter capacity freely placed his professional knowledge at the disposal of the parish, thus rendering material assistance in the carrying out of the main drainage system. His large and unostentatious benevolence, known indeed only to those intimately acquainted with the working of the various charities, his ready sympathy with every form of suffering, practically exemplified by the visits he paid to many poor people, gained him the affection and respect of all classes; whilst his devotion to his work and to the interests entrusted to his charge

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were an example and a stimulus to the large staff under his control.

In the spring of 1881 commenced an illness which he was never altogether able to shake off. Twice during the summer he spent some weeks at Buxton, with apparent advantage to his health; but in the beginning of November he was again stricken down, and rapidly succumbed to the effect of his malady, dying at his residence at Chiswick on the 1st of December, 1881.

He was elected an Associate of the Institution in 1848, and was transferred to the class of Members in 1867.

Dr. MANOEL BUARQUE DE MACEDO was born on the 1st of March, 1837, in the city of Recife, the capital of the province of Pernambuco, Brazil. After pursuing the usual course of study at the military (now the Polytechnic) school of Rio de Janeiro, he, in 1856, obtained the degree of Doctor of Mathematics, and subsequently was Professor of Mathematics in the Imperial College, Don Pedro II°, in the same city. He then visited France, and was for a short time a pupil in the École des Ponts et Chausées. Next he was for two years engaged in various departments connected with the Belgian State railways, and received in 1859, from the University of Berlin, the diploma of Doctor of Political and Administrative Sciences. In 1860 he was appointed fiscal engineer of the Recife and S. Francisco railway, and in 1874, although a member of the Liberal party, Director of the Secretariat of Agriculture, Commerce and Public Works, by the Conservatives, then in power, as they recognised his peculiar fitness for the post. He was at various times elected a member of the Provincial Assembly of Pernambuco, and once of that of Alagoas. He was a deputy-general in 1867, and again in 1878, and took so prominent a part in the legislative discussions of 1878-9 that he was considered one of the leaders in the Chamber of Deputies. He became Minister of Agriculture in 1880, and he died from congestion of the lungs on the 29th of August, 1881, in the city of S. João d' el Rei, Province of Minas Geraes, whither he had accompanied the Emperor for the purpose of assisting at the inauguration of the West of Minas railway.

The Anglo-Brazilian Times of the 1st of September, 1881, thus alludes to Dr. Macedo:—

"Brazil has just suffered a very great loss in the decease of one of her most promising statesmen, the enlightened, far-seeing,

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energetic, laborious, and skilful Minister of Agriculture, Conselheiro Manoel Buarque de Macedo. . . . . Rarely, indeed, has so unanimous a feeling of regret, amounting almost to dismay, been felt among all classes, native and foreign, as found its expression when the news was received of the sudden death of a minister in whom all appreciated the indefatigable industry, the professional aptitude and skill, the broad views for the development of his country, and the unceasing efforts to secure the best results compatible with the sacrifices of the nation. Moderate in temperament, conciliatory in demeanour, open to the reception of reasonings, free from the indolent procrastination which is the great defect of our public men, he was gradually creating a wide-spreading feeling of reliance in his intentions, and capacity to become an active agent in the solution of the most pressing problems of the day—immigration, labour, and viation—and a great and brilliant career as a leading statesman of his country loomed before him in the early future. Unfortunately the very zeal and industry which rendered him so valuable an administrator of a department so important as agriculture and public works is to the prosperity of the country had undermined his health, and sudden exposure to the chills of the mountains of Minas Geraes completed the work of insidious disease, and cut short his life while still in the flower of manhood."

The deceased was a Commander of the Orders of the Rose of Brazil, of the Legion of Honour of France, and of Our Lady of the Immaculate Conception of Villa Viçosa of Portugal.

MR. CARL LOUIS SCHWENDLER[1] was born on the 18th of May, 1838, at Torgau, in Prussia, of humble parentage. Narrow circumstances greatly interfered with the progress of his education, and at one time he was even condemned to the drudgery of a bricklayer's labourer during an interval of obligatory abstention from study. But his natural force of character, combined with great buoyancy of spirits, and a worthy ambition on behalf of a devotedly loved mother, sufficed to prevent his becoming hardened to a state of callous indifference to his humble surroundings. The opportunity which is said to confront every man once in his life found young Schwendler ready. It came in the shape of a happy chance which

[1] This memoir has been compiled from the "Telegraphic Journal and Electrical Review" for January 21, 1882.

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brought him into contact with Dr. Werner Siemens, in the immediate vicinity of whose telegraph works Schwendler had found employment in the office of a gas-engineer. After a short probation, during which he was, on account of his physical strength, employed at the anvil, he was installed in Dr. Werner Siemens's laboratory, helping Dr. Esselbach, Mr. Robert Sabine and others in the re-determination of the Siemens mercurial unit of electrical resistance. He also assisted in making determinations of the conducting power of other metals, besides investigations on the distribution of magnetism in bars. In due course his country claimed the year of service enjoined by its military laws on all able-bodied young men. It is a notable testimony to his worth as well as to the generosity of his chiefs that after so short a period in their employment, Mr. Schwendler was allowed to draw his salary during the interval, as if he had been actually at work. In 1862 Mr. Schwendler was transferred to the London firm of Messrs. Siemens Brothers. He was chief electrician during the manufacture and laying of several cables for the French Government, and in 1863–64 was sent to the Mediterranean to lay one of these cables. Soon after leaving Toulon, Schwendler was attacked by typhoid fever, and had to be left in charge of a good sisterhood until his convalescence allowed of his removal, which, owing to his vigorous constitution, was not long delayed. On his recovery he returned to England and took charge of the electrical department of Messrs. Siemens' cable works at Charlton, where, in addition to routine work, he directed his attention to several favourite subjects. In 1865 he, in conjunction with Mr. Sabine, contributed a short Paper to the British Association meeting.

The following year, in the "Philosophical Magazine," Mr. Schwendler published a valuable Paper "On the most suitable Galvanometer Resistance to be employed in Testing with the Wheatstone Bridge," which subject, till then much neglected, he had taken great pains to investigate both experimentally and mathematically. He retained his appointment with Messrs. Siemens Brothers until 1868, when Colonel Robinson, the Director General of Telegraphs in India at that time, found it necessary to have an experienced electrician in order to introduce uniformity into the system of Government telegraphs. Through the good offices of Dr. C. W. Siemens, Mr. Schwendler was recommended, and accepted provisionally the post of Assistant Electrician to the Director-General of Telegraphs in India early in 1868, and remained in that position as an employee of the firm of Siemens Brothers until the commencement of 1870. Highly appreciated

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for his integrity, ability, and amiability by the whole staff, he was offered by his chief a superior position in the Government service as Special Instructor to the Telegraphic Staff, and acting under the instructions of the Director-General, he, soon after his arrival in India, commenced the preparation of his now well-known "Instructions" for the guidance of the staff of the Government telegraph department there, the object in view being to facilitate the introduction and thorough understanding on the part of the officials of a rational system of testing lines and the technical arrangement of the offices.

The first part of these instructions was printed and issued to the department in 1869 in the form of a book containing about fifty pages, which was well received and met with deserved consideration both within and without the department, in spite of the fact that it was far from complete in its Author's opinion, having been prepared in a hurry under pressure of other work and during almost incessant travelling. The value of these "Instructions" was, however, subsequently evidenced by the fact that much of the contents was soon after quoted in professional text-books, and other telegraph administrations applied to the department for copies. These facts and the friendly encouragement received from the late Colonel Robinson induced Mr. Schwendler to elaborate his systems of testing still further, so that during the following seven years a series of such books was printed by the Government of India and issued. The spirit which animated the Author of this work may be best expressed in his own words in the preface to a reprint published in 1878. He says: "However much testing may become routine by continual practice, it will always, and should always, partake of something of the nature of a physical experiment, which must be conducted with a perfectly clear understanding. Then only can the tester draw the right conclusion from his observed facts, then only can testing become of real benefit to the administration." In India, thanks to his energy and the hearty co-operation of the staff, these conditions have been fulfilled.

Besides the performance of his official duties, Mr. Schwendler was busy with many collateral subjects of investigation, on some of which he contributed Papers to the Asiatic Society, of which he was a member of council, and to the "Philosophical Magazine." In 1870 he investigated and published, "An Arrangement for the Discharge of Long Overland Telegraph Lines," and "A Practical Method of Locating Bad Insulators in Telegraph Lines." In 1872 he published a Paper, "On the Best Resistance of the Coils of any

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Differential Galvanometer," and another Paper, "On Differential Galvanometers;" in 1874 a Paper "On the General Theory of Duplex Telegraphy," and one "On Earth Currents," and in 1876 another Paper "On Duplex Telegraphy." In 1876 he received leave of absence, and returned to Europe to recruit his health. While in England in 1877 he was elected a member of the Council of the Society of Telegraph Engineers and of Electricians, to which he gave his assistance until he returned to India. Early in 1877 he was requested by the Board of Directors of the East-Indian Railway Company to institute detailed inquiries into the position of electric lighting in England, with a view to the illumination of the Indian railway stations. Being, however, soon convinced that the subject was very little understood by the majority of those into whose hands it had fallen, he proposed that before a practical trial was made at any of the Indian railway stations a series of experiments should be instituted, upon which a correct judgment might be based. The Board of Directors having sanctioned the necessary outlay, experiments were commenced at the Indian Office Stores, Belvedere Road, Lambeth. The series which Mr. Schwendler there carried out was an elaborate, and as far as his materials went, an exhaustive one, occupying him until November 1878. Having to return to India, he was unable to finish a complete report before his departure; but he prepared a *précis*, which was printed and issued. During this furlough, on the 4th of December 1877, Mr. Schwendler was elected a Member of the Institution of Civil Engineers.

In March 1879, Mr. Schwendler read a Paper before the Asiatic Society of Bengal,[1] "On the economy, practicability, and efficiency of the electric light for certain illuminating purposes, and on the best means of its distribution;" the substance of the Paper being of course based upon his experiments made in London. In the same year he published a Paper on a new standard of light, and then reverting to telegraphy, another Paper "On a Method of using a Small Fraction of the Main Current provided by a Dynamo-electric Machine for Telegraphic Purposes." This idea became a favourite one, and as late as last year he published a Paper on "Some Experiments to supply all Lines terminating at the Calcutta Station with Currents tapped from a Single Dynamo-electric Machine." Both of these essays have been abstracted in the "Minutes of Proceedings."[2]

[1] "Proceedings of the Asiatic Society of Bengal," 1879, p. 82.
[2] Vol. lx., p. 500; vol. lxiv., p. 435.

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Some years since, Mr. Schwendler suffered from an attack brought on by the heat of the Indian climate, which his natural vigour and robustness enabled him subsequently to disregard, if not absolutely to forget, but which possibly laid the foundation for the fatal illness which necessitated his return to Europe, and to which he at length succumbed.

Those who enjoyed the pleasure of Mr. Schwendler's personal acquaintance will not need reminding of the brightness and almost juvenile buoyancy of his spirits which endeared him to all with whom he came into contact. He was impulsive and enthusiastic in private life as well as in his profession, but whatever he undertook to do, he did with his might, carefully and conscientiously. In the very prime of life and of a career of usefulness he was stricken down by a painful illness, out of which he sank to rest, leaving many a friend and not an enemy. He was essentially a self-made man, and by his energy commanded success, but success did not disturb or damage the purity of his mind and character. Open-hearted and natural he remained from his boyhood till his last days. He did not forget his poorer friends of days long gone by, and he would take the same pride in clasping hands as heartily with the workman of his earliest companionship as he would with men ranking highest in life. In Carl Louis Schwendler science has lost a man who could be ill spared, and who ranked with the highest in the telegraphic profession—and society a man of the purest character and humanity. He died on the 6th, and was buried on the 9th of January, 1882, in the quiet village churchyard of Schoeneberg, near Berlin, followed by a multitude of college friends and professional admirers, lamented by his aged mother whose mainstay he had been through life.

Mr. GEORGE SEATON, the eldest son of the late Mr. George Seaton, of Gothenburg, Sweden, a descendant of the Seatons of Pontefract and Felkirk, in Yorkshire, was born on the 12th of September, 1836. His professional career was commenced in 1855, when he entered the engine works of the late Mr. Wm. Simpson, M. Inst. C.E., as a pupil, and after serving two years in the pattern, fitting, turning, and erecting shops, was sent to assist in erecting the engines for the Copenhagen Waterworks. On returning, he was transferred to the office of the late Mr. James Simpson, Past-President Inst. C.E., with whom his pupilage of five years was com-

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pleted. For the next nine years (1861–70) he was an assistant to Mr. Simpson, engaged in preparing the plans for, and in charge of, the additions and enlargements to the works of the Lambeth, Chelsea, and Stockport water companies.

In 1870 Mr. Seaton obtained the post of assistant-engineer to the Pest Waterworks, and during his four years' residence on the Continent he was employed in making plans and estimates for waterworks in many of the principal towns in Austria, Hungary, and Russia. In June 1874 he was appointed assistant-engineer to the East London Waterworks Company, and in the following year engineer-in-chief, and in that capacity designed and successfully executed extensive additions to the works at Lea Bridge, Woodford, and Buckhurst Hill, including filter-beds, covered reservoirs, a high-service tank, and two sets of pumping engines. Mr. Seaton was permitted by the directors to act as consulting-engineer to the Turin Waterworks, and he revised the plans of the Italian engineers.

During the year 1879 Mr. Seaton became a Fellow of the Royal Geographical Society, and on the 4th of May, 1880, he was elected a Member of the Institution of Civil Engineers.

Mr. JOHN TAYLOR, born at Holwell, near Tavistock, on the 11th of August, 1808, was the eldest son of Mr. John Taylor, who resided there while managing engineer of the Wheal Friendship copper-mine and other mines in the Tavistock district, and who was subsequently well known, while a member of this Institution, as a Fellow of the Royal Society, of the Geological Society, as Treasurer of the British Association for the Advancement of Science, and as a Member of the London University.

The subject of this memoir, and his brother Richard, began their education at Charterhouse School, and completed it at the Manchester College, York. No institution for special mining instruction existing in England in those days, Mr. Taylor, senior, after giving his sons opportunities of acquiring much knowledge of practical mining in the mines under his management in this country, sent them to Germany, where they spent nearly the whole of the year 1828 in visiting the principal mines of the Rhenish provinces, the Hartz, Freiberg in Saxony, Hungary, Southern Austria, and Bavaria. Soon after his return from Germany at the end of that year, Mr. John Taylor, junior, was

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appointed by his father to a position in the management of lead mines in Flintshire, which were then in great activity. Eventually he took the chief management of the Great Mold Mines and of the Halkyn Mines in the same county. He remained at this work for many years, during which time he, under his father's direction, took an active part in the opening out of some of the long-abandoned mines of Cardiganshire, and soon brought them into a very prosperous condition. His attention was not, however, confined to Flintshire and Cardiganshire, but embraced also the Grassington mines in Yorkshire and the Minera Mine in Denbighshire, where he employed a water-pressure engine of immense power, designed by the late Mr. Darlington, then an engineer in Mr. Taylor's service.

In the year 1845 he was admitted into partnership by his father, and in 1853 the management of the Linares Mining Company came into the hands of Messrs. John Taylor and Son, and the knowledge which the junior member of the firm had acquired by his visits to Linares led subsequently to the formation of the Fortuna and Alamillos Companies, which may be regarded as the pioneers of English enterprise in that part of Spain.

The remarkable discovery of silver at Hien del Encina, in the province of Guadalaxara, about this time engaged the attention of Messrs. John Taylor and Son, and offered an opportunity for the application of the most improved process for the reduction of the ores of that metal. Having, from their connection with the mines of Mexico, been led to study the German processes, and having gained a complete knowledge of the practical working of those processes, they formed the Bella Raquel Company. A leading part in the planning of the Fabrica La Constante for this company was taken by the subject of this memoir. This establishment, in which the Freiberg process of amalgamation was carried out, with the advantage of improved English machinery, with great success, yielded to the company large profits as long as the mines of the district, which were all worked by Spanish companies, continued to supply a sufficient quantity of ore for their employment. Contemporaneously with these enterprises Mr. John Taylor organised the machinery and plan of working the mines of Palhal and Carvalhal in Portugal, which, during many years, yielded a considerable produce of argentiferous copper ores with ores of cobalt and nickel. The attention of the firm was not confined to Europe; they had undertakings in Central America, in Canada, and in Western Africa. In the year 1851, Mr. Richard Taylor joined the firm from Cornwall, and the business of Messrs.

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John Taylor and Sons has, since that date, been continued on a constantly increasing scale, including the Cape Copper Mines, and numerous other metallic mines of every description. In 1853 Mr. John Taylor made an inspection of the argentiferous lead mines of Pontgibaud, which led to an Anglo-French company being formed under the auspices of his firm, Messrs. John and Richard Taylor holding the position of chief engineers, and conducting the entire practical management of the mines and smelting works.

"The Mining World and Engineering Record," of the 23rd of April, 1881, thus refers to the subject of this memoir:—

"At the periodical meetings of his companies Mr. John Taylor was a welcome and a fluent speaker. No gathering was considered complete which was not addressed by him or by his brother. He had the peculiar faculty of being able to explain mining operations with an absence of technicalities which must often have been welcome to those whom he addressed. His descriptions of plans and sections were singularly clear, and gave to the most uninitiated in the mysteries of mining a clear notion of what was going forward. He was most careful in his statements, and never led his hearers to indulge hopes which events were unlikely to realise. His forecasts of the probable results of mining operations were often surprisingly accurate, and no shareholder ever left his meetings who could truly say that all the information he asked for had not been forthcoming. In fact the public learned to rely greatly upon him, and so it came to pass that the name of John Taylor and Sons upon the face of a prospectus went a long way towards the successful floating of new enterprises.

"In his business relations Mr. John Taylor was not merely as open as the day, but united to his other qualities a kindly, courteous, and genial manner, which endeared him to all who knew him, and particularly to his numerous staff. The service they rendered him was the service of love, and not that of which mere pecuniary emolument is the reward. By them he will be sorely missed, whilst to his brother his loss is simply irreparable."

Mr. Taylor was elected a Member of the Institution in April 1847, and occasionally took part in the discussions. He was also a Fellow of the Geological Society, and a Member of the Institution of Mechanical Engineers and of the British Association. He died at his residence at St. Albans on the 20th of April, 1881, at the age of seventy-two.

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Mr. ROBERT RICHARD ARNTZ, son of a Prussian army contractor, was born at Erefeldt, in Prussia, in 1815. His mother was an Englishwoman, a sister of the late architect, Mr. Robert Cantwell, and he was brought to England by her when four years old to escape some threatening political disturbances, and never returned to the land of his birth. He received an English education, and as soon as facilities were given for doing so he was naturalised a British subject. After two years spent in Paris, he was articled at the age of sixteen to the late Mr. W. Herbert, then one of the most eminent London builders. Under him he devoted most of his attention to surveying and architecture, and soon after the conclusion of his apprenticeship he was entrusted by Mr. Herbert with the agency and surveyorship for his several house properties in different parts of London, and retained this appointment till his death. This introduction soon brought similar commissions for other people. In 1844 he was elected surveyor to St. John's parish, Westminster, and shortly afterwards this appointment merged into the surveyorship to the Westminster District Board of Works, which he filled till his death. He was also surveyor to most of the old Westminster charitable institutions, and to several private estates, and for most of his clients he himself carried out such architectural works as became necessary from time to time. At an early date he devoted great attention to the question of hygiene, with especial regard to house-drainage and public sewerage; and for general use in the Westminster Board of Works district under his care, he published regulations and plans for house-drainage and water-supply, which have since been adopted in many other places. One of his earliest architectural commissions was the decoration of St. John's Church, Westminster; and a repetition of the same duty was about his last, being only completed a few weeks before his death. Among his architectural works were the rebuilding of Monmouth church steeple; the adaptation of Cromwell House, Highgate, as a convalescent home for sick children; sundry alterations at the Albany, to which he was surveyor; the building of the United Westminster Schools in Palace Street, S.W., and new almshouses in Rochester Row, Westminster, for the Palmer and Hill's Charities, which last-named work he was engaged upon when he died.

During the last two or three years, the rapid introduction of wood pavement in his district gave Mr. Arntz increased work and anxiety, as he was one who trusted little to assistants, preferring to look after every detail himself. Unfortunately, he carried his

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personal care and anxiety too far, and for the sake of his clients' interests sacrificed his own health. For some years before his death he took no real holiday, though failing health and anxious friends constantly reminded him of the necessity for such relaxation. The final result was that a slight attack of rheumatic gout at the end of January completely prostrated him; there was no rallying power left, and he died on the 17th of February, 1882.

Though Mr. Arntz's profession was that of an architect and a surveyor, a great deal of his work was of an engineering character, and he took deep personal interest in engineering matters generally. He was elected an Associate of the Institution of Civil Engineers in 1856, and for many years was a regular attendant at the evening meetings. He was a Member of Council of the Social Science Association, and took an active part in its proceedings. In 1862 he was elected a Fellow of the Society of Antiquaries.

In his professional work Mr. Arntz was extremely precise, and careful to define clearly every detail of a projected work, holding the opinion that such precision and care were as much due to the contractor as to his client. It will readily be understood that a man so careful in his specifications and plans always insisted on having his works well carried out. When once his plans were completed, he rarely altered them; and when, in his capacity as public surveyor, he had once made up his mind that a certain line of action was the right one to follow, nothing would make him swerve from it. For his clients he was a most indefatigable hard worker, never sparing himself when he could advance their interests. The slightest suspicion of unfair dealing or bribery, in any shape or form, offended him greatly, and he was most unsparing in his denunciations of such practices.

Mr. Arntz's long residence in Westminster, and his connection with so many of its public and charitable institutions, gave him a large circle of friends, by whom he was much respected.

MR. PHILIP HARRISON HOLMES, who was born at Ridlington, Norfolk, on the 16th of December, 1854, was the third and youngest son of the late Rev. Richard Holmes, Vicar of Happisburgh, Norfolk. At an early age he became a pupil in Mr. Craske's school at Bury St. Edmunds, after which he studied with the Rev. Dr. Roberts, at Croydon. Subsequently, being desirous of becoming a Civil Engineer, he was articled to Mr. James Abernethy, Past-

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President Inst. C.E., for three years (February 1874–77), and was then engaged in marine and land-surveying and in the office. On the expiration of his pupilage he was appointed assistant resident engineer for the extension works of the Alexandra dock, at Newport, Monmouthshire, which included the construction of a graving dock, timber wharf, &c. On the completion of these works, he, in 1879, obtained an appointment as assistant-engineer to the Conservators of the River Thames. Whilst discharging the duties connected with this post, he, in January 1881, contracted a severe cold, complications ensued, and in the autumn he was threatened with a fatal disease. Change to a milder climate was of no avail, and he died on the 12th of November, 1881, at Castellamar di Stabia, Italy, leaving a wife and two children. He was very fond and proud of his calling, and was elected an Associate-Member of the Institution on the 4th of May 1880.

MR. JOHN MILTON LEWIS was born at Clifton, Bristol, on the 19th of February, 1846, and was educated at the Bristol Grammar School and at King's College, London. He served a pupilage of three years (May 1866 to 1869) to the late Mr. James Samuel, M. Inst. C.E., and remained in the same office for a short time as an assistant. From September 1869 to August 1872 he was employed on the Poti and Tiflis Railway, in the Caucasus, in charge of the construction of 60 miles, under Mr. Preston, Chief-Engineer for Messrs. Crawley and Co., contractors. From August 1872 to February 1873 he had sole charge of a survey for 35 miles of railway in Roumania, the plans for which were accepted by the Government, and the concession obtained. From June to November 1873 he had partial charge, and from November 1873 to March 1876 sole charge, of surveys for a line and branches 300 miles long in Roumania, called the Black Sea Railway. From March 1876 to January 1878 he had sole charge of the construction of a portion of the Ploesti and Predeal Railway for the late Mr. John Marshall, sub-contractor to Messrs. Crawley and Co., and after his death for the trustees. In the year 1878 he went to South Australia, where he carried out, in partnership with Mr. T. Marshall, the contract for the construction of the Kapunda reservoir. From September 1880 to his death in June 1881 he had sole charge of the construction of 60 miles of railway between

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Quorn and Orroroo in the same colony. He died after five days' illness on the 22nd of June, 1881, from the effects of a chill. Mr. Lewis was elected an Associate of the Institution on the 20th of May, 1873.

Mr. HENRY CRABTREE was the eldest son of Mr. Matthew Crabtree, of Leeds, and one of a family most of whose members are connected with the railway interest. He began his career with the Great Northern Company. He was early appointed their agent at Leeds, and rapidly rose to the position of District-Superintendent, and in 1863 was put in charge of the London section of the line.

In 1865 he was appointed general manager of the Northampton and Banbury Junction Railway, and two years later was selected for the important post of general manager of the Northern Railway of Buenos Ayres. This was at a time when the railway was labouring under difficulties, and Mr. Crabtree succeeded in substantially improving the position of the company. The official estimation of his services was agreeably shown by the presentation to him by the directors of a sum of £1,000. In addition to his appointment with the Northern Railway, Mr. Crabtree accepted the management of the Buenos Ayres and Ensenada Port Railway, and he held these two appointments up to the date of his demise.

Mr. Crabtree had been in failing health for some months, and was returning to England for rest, but unfortunately succumbed to an attack of heart disease shortly after reaching Southampton, dying on the 18th of April, 1882, at the early age of forty-five, much regretted by his friends at home and in Buenos Ayres.

He was elected an Associate of the Institution on the 7th of February, 1871.

Mr. SAMUEL JOHN KNIGHT was born in London in 1809, and was educated at the school of Mr. Fennell, at Wimbledon. When under fourteen years of age he lost his father, and soon after was placed, by the advice of his uncle (the late Mr. James Mackell, of Park Lane), in the house of Messrs. Parkes and Pfeil, iron merchants. Messrs. Maudslay had previously signified their willingness to take him into their works; his mother much wished him to accept their offer, but his uncle objecting, it was declined.

About the year 1832 he entered the works of Messrs. Bramah and Robinson, engineers. Mr. Timothy Bramah, an old friend

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of his family, had the entire management of the engineering department, and perceiving at once young Knight's ability, took every opportunity of employing him with, and introducing him to, the chief engineers of the day. During this time, on the 20th of February, 1838, he was elected an Associate of the Institution, being proposed by Sir Isambard Brunel. In 1839 he left Messrs. Bramah and Robinson's, and took a foundry at Maidstone—at first alone, and afterwards with a partner; this business, however, was given up in 1851. He had now become known to, and had long had business relations with, Mr. Edward Ladd Betts, who, finding that he was disengaged, at once called upon him, and thus began a pleasant connection which lasted until the death of Mr. Betts. From this time he devoted himself to various works, in which the firms of Messrs. Peto and Betts, Brassey and Wythes, Lucas Brothers, Waring Brothers, as well as the American merchants, Sir Curtis Lampson and Co., Robert Benson and Co., and T. S. Morgan and Co., were among many others engaged. Business poured in upon him from many quarters, and he was frequently consulted, both at home and abroad, in valuations, arbitrations, and other matters of the kind. Being a man of good constitution, his power of bearing fatigue was great; he would not unfrequently travel and work twenty hours a day for six days together, and then would journey from one end of the kingdom to the other for the sake of spending the Sunday in his quiet country home with his family. He had bought a small estate in Surrey, the improvement of which was a great source of interest and amusement to him during the latter years of his life. He died on the 4th of December, 1881.

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SECT. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

On the Delineation of the State of Stress and Strain in a Particle. By Prof. MOHR.

(Der Civilingenieur, 1882, p. 113.)

The point P, for which the state of stress has to be represented, may be considered as the centre of a sphere K, whose radius is infinitely small. Suppose another sphere K′ concentric with K, but with the finite radius σ', and let Q be any point on K, and Q′ the point where the produced radius P Q cuts K′. From Q′ let a line Q′ R be drawn equal and parallel to the stress ρ in the point Q. The Author shows that for a state of equilibrium the locus of the points R is the surface of an ellipsoid whose three axes P X, P Y, P Z determine three planes in which there is no shearing stress, but only the normal stress σ_x σ_y σ_z; these planes are called the principal sections of P. The notation is chosen so that $\sigma_x < \sigma_y < \sigma_z$.

If the arbitrary radius σ' be put equal to σ_z the ellipsoid becomes flattened out into a plane surface bounded by an ellipse lying in the X Y plane.

Let $\xi\,\eta$ and $\xi'\,\eta'$ be the co-ordinates of R and Q′ in the X Y plane; the Author shows that:

$$\frac{\xi}{\xi'} = \frac{\sigma_z - \sigma_x}{\sigma_z} \text{ and } \frac{\eta}{\eta'} = \frac{\sigma_z - \sigma_y}{\sigma_z}.$$

This gives a means of determining the amount and direction of the stress at any point Q when σ_x σ_y σ_z are known.

From the above consideration the Author proceeds to the development of his stress diagram; in this the position of Q on K is supposed to be given by the angle ϕ which P Q makes with the X Y plane, and the angle ψ which the plane Z P Q makes with the Z X plane. Let the stress ρ at Q be resolved into two components σ and τ, the first normal and the second tangential to the sphere K, and let τ be further resolved into two tangential stresses, one, τ', parallel to the X Y plane, and the other, τ'', cutting the Z axis. The Author shows that—

$$\sigma = \sigma_z - \cos^2\phi\,\{(\sigma_z - \sigma_y) + (\sigma_y - \sigma_x)\cos^2\psi\}$$

$$\tau' = (\sigma_y - \sigma_x)\sin\psi\cos\psi\cos\phi$$

$$\tau'' = \{(\sigma_z - \sigma_y) + (\sigma_y - \sigma_x)\cos^2\psi\}\sin\phi\cos\phi$$

$$\tau = \sqrt{\tau'^2 + \tau''^2}.$$

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The graphical interpretation of the above equations leads to the Author's diagram, which lies entirely in a plane. The complete proof is given in the Paper.

Take two rectangular co-ordinate axes $O\sigma$ and $O\tau$, and on the σ axis lay off $OX = \sigma_x$, $OY = \sigma_y$, and $OZ = \sigma_z$; then describe three semicircles on XZ, XY, YZ, all towards the same side of the σ axis. The three-cornered space bounded by the semicircles may be considered as the graphic representation of an octant of the sphere, in such a manner that to find the point Q′ in the diagram corresponding to Q of the sphere a point A is found on the circle XY, and a point B on the circle YZ, such that the angle AYO equals ϕ, and BZO equals ψ; through B describe an arc concentric with the semicircle XY, and through A and Z describe an arc from a centre on the σ axis, the intersection of the two arcs will give Q′; this construction gives in the diagram a system of circles corresponding to the latitude and longitude circles which fix the position of Q on the sphere. Q′ being found, the abscissa gives the normal stress σ, the ordinate the tangential stress τ, and the radius-vector the resultant stress ρ at the point Q on K.

The Author next considers the deformation of a small homogeneous sphere whose centre is P, and whose elasticity is supposed to be the same in all directions; he shows that the strain at any point Q on the surface of the sphere may be expressed as a function of ψ ϕ and three strains λ_x λ_y λ_z in the direction of the three stresses σ_x σ_y σ_z; the strain at Q may be resolved into a normal strain λ and a tangential strain δ, and all the previous equations hold good by merely changing the notation σ τ' τ'', &c., to λ δ' δ'', &c. A strain diagram can therefore be constructed similar to the stress one.

It is found by experiment that when $\sigma_x = \sigma_y = 0$,

$$\lambda_z = \frac{\sigma_z}{\epsilon} \quad \lambda_y = \lambda_x = -\kappa \frac{\sigma_z}{\epsilon},$$

where ϵ is the modulus of elasticity, and κ a constant lying between 0·25 and 0·3.

If it be assumed that when σ_y and σ_z are not equal to 0, they act in a similar manner to σ_x, then

$$\lambda_x = \frac{\sigma_x - \kappa(\sigma_y + \sigma_z)}{\epsilon}$$

$$\lambda_y = \frac{\sigma_y - \kappa(\sigma_x + \sigma_z)}{\epsilon}$$

$$\lambda_z = \frac{\sigma_z - \kappa(\sigma_x + \sigma_y)}{\epsilon}.$$

It follows from this and the previous considerations that

$$\frac{\lambda_x - \lambda_y}{\sigma_x - \sigma_y} = \frac{\lambda_y - \lambda_z}{\sigma_y - \sigma_z} = \frac{\lambda_z - \lambda_x}{\sigma_z - \sigma_x} = \frac{\lambda_z - \lambda}{\sigma_z - \sigma} = \frac{\delta'}{\tau'} = \frac{\delta''}{\tau''} = \frac{1 + \kappa}{\epsilon}.$$

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If, therefore, the scales be chosen so that the stress ϵ and the strain $(I + \kappa)$ are measured by the same line, the same diagram can be used for stress and strain, the only difference being that the τ axis does not necessarily coincide with the λ axis. The X Z circle in the diagram is called the principal circle, as it gives the limits within which $\sigma\tau$ and $\lambda\delta$ vary.

If the stresses be found experimentally, which, being applied in various manners, just strain a body to the limit of elasticity, the principal circles can be drawn in the diagram for these states, and the envelope of these circles will give a graphical representation of the elastic limit; if, then, the principal circle of any other condition be drawn that it is wished to investigate, it can be seen if the elastic limit is reached or exceeded; similarly with the breaking limit. The results throw some light on the influence of cross-strain, and show that the linear extension of a body is by no means a measure of the approach to the breaking or elastic limit.

The latter part of the Paper contains practical applications of the Author's diagram, and a discussion of the phenomena produced by tension, compression, punching, and shearing.

W. P.

Note on the Economy of the Windmill as a Prime Mover.

By ALFRED R. WOOLF.

(Journal of the Franklin Institute, vol. lxxxiv., 1882, p. 21.)

In this Paper the Author gives some tables of practical results obtained with windmills, and shows that for small powers they are a commercially economical motor.

There is also a diagram of the best angles for the vanes; this is plotted from the Author's formula,

$$\tan a = \frac{v}{c} + \sqrt{1 - \left(\frac{v}{c}\right)^2}$$

in which a represents the angle of impulse of the wind on the windmill-blade at any given point, v the velocity of the blade at that point, and c the velocity of the wind. A Table is also given showing the relation between the velocity and pressure of wind, and the effect of temperature on the pressure.

W. P.

Maintenance and Rolling[1] *of Macadamised Roads.*

By A. DEBAUVE.

(Annales des Ponts et Chaussées, 6th series, vol. iii., 1882, p. 659.)

A detailed comparison is drawn between the relative advantages and disadvantages of the maintenance of roads in the country by patching and by rolled layers; and also between rolling with

[1] Minutes of Proceedings Inst. C.E., vol. lxix., p. 425.

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horses and by steam. The advantages of the system of repair by patching are, great simplicity, and a regular profile of road; the disadvantages are, loss of material, and injury to the traffic. The system of layers appears more costly in the first instance than patching; but the expenses of cleaning and sweeping, the crushing and shorter duration of the metalling, and the inconvenience and the harm done to the traffic in the latter case, more than balances this in the case of roads of any importance. The advantage of layers over patching is greater in proportion to the cost of the road metal; and the only serious drawback to the system is that, towards the close of the life of a layer, the road, having become hollow in the centre, is liable to be rapidly deteriorated in a very rainy season.

After giving some information on the best thicknesses for layers of metalling, and the points to be attended to for securing a good road, the Author proceeds to the consideration of horse and steam rollers. As the resistance to traction is much greater over a new layer at the commencement of the rolling than towards the end, whilst the number of horses harnessed to a roller remains the same, it is advantageous to be able to double the weight of a roller. The Moquet roller realises this condition, having a weight of from about $3\frac{1}{2}$ to $4\frac{3}{5}$ tons when empty, which can be increased to from 7 to $7\frac{1}{2}$ tons by filling two large, deep cases with gravel. The balance is secured by placing one case in front, and one behind the roller; and the lowness of the centre of gravity gives great stability. It is important that the roller should turn easily, to avoid having to unharness the horses; and the system in which the roller is formed, of four similar rings side by side, accomplishes this. An index recording the number of revolutions, with which the steam rollers are provided, would be a very useful adjunct to horse rollers. The heaviest rollers are the best for rolling new layers of metalling; but the weight is practically limited to what six or seven horses can draw, the largest number which is readily procurable, and which can be easily managed; and about 7 to 8 tons is the heaviest roller they can draw properly. The cost of traction with horses on main roads, with gradients not exceeding 1 in 33, allowing a turn for every 220 yards, is about 3*s.* 6*d.* per mile, and about $13\frac{2}{3}$ miles are traversed in a day of ten hours.

Four steam-rollers were purchased, within the last three years, for forming and repairing several main roads in the department of Oise, as it was doubtful whether sufficient horses could be procured for rolling in the ordinary way. Each roller cost £480, and weighed from 10 tons to $11\frac{1}{4}$ tons, according to its load of water and coal. The minimum pressure exerted by the steam roller per foot of width is $1\frac{1}{2}$ ton, which is the same as that of the half-loaded horse roller, whose smaller width compensates for its lighter weight. Owing to the greater width of the steam roller, a day's journey of $8\frac{2}{3}$ miles with it is equivalent to the $13\frac{2}{3}$ miles of the horse roller, and this distance is easily accomplished by the steam roller, so that its effective work is at least equal to that of a horse-

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roller with six or seven horses, on roads with moderate gradients. In the exceptional case of gradients from 1 in 33 to 1 in 20, the steam roller is much more advantageous. The cost of traction with the minimum of six horses, is 38*s.* 4*d.* per day; whilst with the steam roller it is as follows:—

	s.
Driver	8·0
Coal, 3·2 cwts. at 32*s.* per ton	5·12
Oil, waste, wood, &c.	2·08
Allowance for cleaning and stoppages	2·0
Total per day	17·2

which is less than half the cost of traction with horses. The actual cost of traction with a steam roller, in the Author's district, per cubic yard of material used for repair, during 1880–82, amounts to 8½*d.*; whereas the mean cost in another district, with horse-rollers, was 15*d.*, making a saving with steam rolling of 6½*d.* per cubic yard, or a total saving of £366 in two years. On this estimate, the cost of the steam roller would be saved in three years; and as, in the special work accomplished by the steam rollers, the cost with horse rollers would have really reached 25½*d.*, instead of 15*d.*, the steam rollers have already effected a saving exceeding their cost. The possible objections to the use of steam rollers are shown to be immaterial; and the conclusion arrived at is, that steam rolling marks an important progress in the maintenance of ordinary roads.

L. V. H.

Improvement of Great Kanawha River.[1]

(Report of the Chief of Engineers, U.S. Army, 1881. Part I., p. 911.)

The state of the works at the close of the financial year ending 30th June, 1881, is described in the report. Two locks with movable weirs had been in regular work during the year; another lock and weir were to be finished by the end of 1881, and a fourth lock was begun. Details about the working of the movable weirs are given. The two dams were completed in July 1880, and had each been lowered and raised three times up to the 1st of June, 1881. The number of consecutive days they remained up varied from thirteen to sixty-five. The hours of labour expended in raising them varied from sixty-six to two hundred and ninety-three, and in lowering from thirty to one hundred and seventeen. The working is stated to be satisfactory, and has become much quicker as experience is gained. The tripping bars cause the principal trouble, as they get choked with gravel, cinders, and débris, especially when the weir is down, which renders a consider-

[1] Minutes of Proceedings Inst. C.E., vol. lxiv., p. 373.

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able amount of clearing by a diver necessary before the weir can be raised. The tripper also is liable to fail in releasing the prop if the prop is not quite in its place, which can only be secured by the diver examining each one in the process of raising. To remove these objections, the adoption of the Pasqueau system of double-grooved shoe,[1] which dispenses with the use of a tripping bar, is advocated. It is found that a considerable accumulation of material takes place just below the sill of the foot-bridge of the weir during every flood, preventing the lowering of the shutters till cleared by the diver. To remedy this, it is proposed that the sill should be placed further up stream, and given as much slope as possible on the down-stream side. The breaking up of the ice in the river, though from 5 to 8 inches thick, did no injury to the movable weirs. The weirs had been up more than half the time that they had been in operation, and the river had for the first time been rendered navigable.

L. V. H.

The Panama Canal. By H. Hersent.

(Mémoires de la Société des Ingénieurs-civils, Paris, 1882, p. 632.)

Mr. Hersent gives an account of a visit to the works of the Panama Canal, in progress, between Colon, on the Atlantic coast, and Panama, on the Pacific coast. Colon he describes as a town built on a low coral rock, standing 3 or 4 feet above the level of the sea. The railway occupies the north shore, and the wagons circulate in front of the first row of houses, without an enclosure, or even a guardian of any kind to warn off passers-by. The aspect of the ill-kept wooden houses, the disorder of the streets, the pools of foul water, the *débris* of burnt refuse, the odour of the natives, excite a disagreeable impression. The departing steamer is regarded with regretful gaze, and already the newly-arrived traveller is afflicted with nostalgia. Nevertheless, the port of Colon is of some degree of importance. It is visited by the fleets of the "Compagnie Transatlantique," the Royal Mail Company, the Pacific Mail Company, the New Orleans Company, besides Spanish steamers. The wagons of the railway company have access to the wharves. Colon exports monthly from 500 to 1,000 tons of bananas, collected mainly from the valley of the Chagres.

Operations for the construction of the canal were commenced by the despatch of the *personnel*, under Mr. Armand Reclus, January 5, 1881. Of these, with others who arrived subsequently, 7 per cent. have died. The line is laid out for more than half the length, and the surface has been cleared of trees and undergrowth. The site of the barrage in the valley of the Chagres, for the regulation of its flow, has been explored and cleared of vegetation. The port of entry at Colon will probably be excavated at Fox River, where

[1] Minutes of Proceedings Inst. C.E., vol. lxiv., p. 372.

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a temporary port has been established for the reception and storage of material. Thence the canal, skirting the morass of Mindi, passes into the valley of the Chagres at Gatun, whence the line follows the valley to San Pablo, between the railway and the river on the left side, cutting the river at several points, and crosses the railway at San Pablo. The line of the canal passes thence to Matachin, cutting many bends of the river, and following generally the right bank, which is quitted at Matachin, where the canal will enter the valley of the Obispo. Throughout this length, 28 miles, the soil consists generally of alluvial clay. The port at Colon will be dredged through coral.

At Matachin the river, at lowest water, is 44 feet above the level of the sea. The average fall of the bed of the river is only 1 in 3,300, the feebleness of which accounts for the occasionally enormous floods. From Matachin the line enters the valley of the Obispo, leaving the railway on the right. The surface is very irregular until Emperador is reached, 2¼ miles from Matachin, at a level of about 200 feet above the sea. The summit is reached at Culebra, whence the line follows the valley of the Rio Grande to the sea. The principal cutting is about 9½ miles in length, and 130 feet deep. It could have been avoided if Sir F. de Lesseps would have been contented with a canal of five or six locks. The line through this cutting has been laid out with curves of about 1 mile radius, and the railway is crossed at two points—San Pablo and Culebra. The total length of the canal is 46 miles.

The rise of tide at Panama is 21 feet; whilst at Colon it is little more than 3 feet. To provide against the danger of the floods, at Matachin and above it, a barrage is to be constructed to control the flow, at a place between the Pelado and San Juan hills, where the valley is only 300 feet in width. Already, from 30,000 to 40,000 cubic yards of earth has been removed. Labourers are imported from Carthagena and Jamaica, and even from China. What chiefly affects European workers is the heavy, moist heat, with the different food. The night is as hot as the day; but in the morning the wind is fresh. The greatest danger arises from chills, which induce rheumatism and fever.

At the end of March, 1882, 9 miles of railway had been laid, two hundred earth wagons were on the works, and twelve heavy locomotives.

D. K. C.

Description of the more recent methods of Transport on Rivers and Canals and their employment in Germany.

By J. Klett.

(Zeitschrift für technische Hochschulen, 1881, Nos. 7 and 8.)

In the earliest experiments made on the Elbe in 1720 a hempen rope was fastened on shore, the other end wound up on board and vessels propelled in this way, and nothing better than this rough

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system obtained for a hundred years, when, in 1820, Messrs. Tourasse and Courteaut designed special flat-bottomed tugs 75 feet long and 17 feet wide, with a horse-capstan for winding up the rope, and subsequently (on the Seine) a 6-HP. steam-engine was substituted for the horse-capstan.

Chains next took the place of hempen ropes, and between 1820 and 1830 many chain-tugs were employed on French rivers; but the first systematic service was carried out in 1846 between Paris and Montereau (65 miles) with tugs designed by Mr. Dietz, which in their essential parts of construction, are similar to those in use at the present day. These tugs drew 18 inches of water, and were fitted with engines of from 35 to 40 HP. actuating the drum on which the chain was wound, two sets of gearing being provided for going up and down stream respectively. The boiler-pressure was $5\frac{1}{2}$ atmospheres, and the expenditure of fuel $5\frac{1}{2}$ lbs. per HP. per hour. Subsequently the chain was laid further up the Seine and also applied to rivers in France.

In Germany in 1866 chain-tugs were running on 200 miles of the Elbe; and in the next ten or twelve years this system was in use on the Saale, the Brahe and the Neckar.

The Elbe tugs are 138 to 150 feet long, 24 feet wide, with 18 inches draught. On the other rivers they are somewhat smaller. The sides are of $\frac{1}{4}$-inch iron plate, and formerly the bottoms were of $\frac{1}{2}$-inch iron, but now they are built of 4-inch pine planks, as suffering less from abrasion on dragging over a rough bed. There is a rudder at each end, the wheel being amidships. The engines are from 60 to 70 HP., and work with a pressure of 5 to 7 atmospheres, with expansion and partial condensation. In slight currents a single drum is sufficient, the chain being kept pressed against it by rollers, and the drum nicked to prevent the slip of the chain, but ordinarily there are two drums to which the engine power is transmitted by two sets of gearing with different rates of speed—one for working up stream with great power and small speed; the other, down stream with less power and greater speed. Projecting over each end of the tug are booms furnished with guide-rollers for the chain; these booms increase the facility of steering.

The chains are from $\frac{3}{4}$ to 1 inch thick. When fractures occur, which is seldom, it is generally at the moment of the chain being first wound round the drum. Each drum is fitted with a brake, and at the ends of the booms are clips to prevent a running out of the chain in case of the brake failing to hold.

Chain-towing has so increased on the Elbe, that in 1874 there were twenty-eight tugs running regularly between Hamburg and Aussig (420 miles). On the Neckar, at the same period, five tugs were employed on 56 miles of chain, and this was to be extended for 30 miles more, from Heilbronn to Cannstatt. Experience has shown that chain-tugs have great advantages over paddle-tugs even in smooth water; for in the latter 60 to 70 per cent. of the power is lost in slip, and another great advantage of chain-towing is that there is no wash or swell.

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The charge for transport averages about ¼*d.* per ton per mile, which is twice as cheap as the lowest railway charges.

In 1865 Mr. de Meseil, a Belgian, introduced a system of transport where a wire rope was substituted for the chain; this was taken up and improved by a German engineer, Max Eith of Wurtemberg, and worked with great success on a 40-mile section of the Maas (from Namur to Liège). It was subsequently employed on canals in Holland and Belgium, and also on the Rhine; and resulted in 1870 in the formation of a wire-rope tug company under the management of Mr. T. Schwartz. Extensive trials were also made on the Danube about the same time with very satisfactory results, the useful effect being 77 per cent.

In 1873 the above company laid down the line from Bingen to Rotterdam, but worked the upper section only themselves, viz. from Bingen to Ruhrort (155 miles). From Ruhrort downwards a concession was granted to a Dutch company, who employed a special kind of tug in which the rope passed over drums inside the vessel, similar to the chain-tug system; but the usual arrangement of having the rope outside the tug is most convenient, as it enables it to be easily cast off and taken up again when two tugs meet.

The rope used on the Rhine is formed of forty-nine wires 0·189 inch thick, is 1·7 inch in diameter, and weighs 4¾ lbs. per yard. It costs 10*d.* per foot, which is about one-third the weight and cost per foot of an iron chain of equal strength.

Wire-rope tugs are also employed on the Oder and the Neva, and on the Erie Canal they have almost superseded the celebrated "Baxter" steamboats.

The first wire-rope tugs at work in Holland and Belgium had a 20-HP. engine for the driving-wheels, and another 10-HP. engine to work a screw when going down stream clear of the rope. At each end, outside the tug, are guide-wheels to keep the rope clear of the vessel, and at the centre are two large wheels which lead the rope on to a Fowler's clip-drum against which it is kept pressed by small rollers. (To pick up the rope and pass it over the wheels and drum takes a quarter of an hour.)

The Danube Company's tug "Nyitra," to which the Rhine tugs are very similar, is 140 feet long, 24½ wide, and draws 3½ feet of water; the clip-drum is 10½ feet, and the adjoining wheels about 9 feet in diameter. Against a current of 4¼ feet per second it can draw eight barges with a total load of over 2,000 tons at a speed of 3 miles an hour, with useful effect of 75 per cent. In chain-tugs this percentage is higher on account of the greater flexibility of the chain. Fractures of the rope seldom occur, in spite of the rocky bottom in certain sections, and the life of a wire rope may be taken at from four to six years.

Wire-rope tugs cannot work in less than 3 feet of water, or only with difficulty, whereas chain-tugs can work in half that depth. As regards steering facility they are equal. The delay caused by fractures is an important item in the comparison, and repairs to chains occupy considerably less time than repairs to wire ropes. To

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sum up: chain-tugs in depth under 3 feet and in sharp curves are preferable to rope-tugs; in moderately strong currents and larger curves they are about equal; but in canals, and in large deep rivers rope-tugs are best, and both are superior in ordinary circumstances to paddle-tugs.

In canal tunnels, as in the 4-mile section (Monts to Paris), where steam cannot be used on account of the smoke, chain-tugs worked by a horse-capstan tow a barge through in one-third the time and at one-fourth the cost of the former system when men were employed for towing.

On the Rhine and Saone, where particularly strong rapids are met with, special steamers called "grapins" are employed. The "grapin" is an iron wheel of about 20 feet in diameter and 17½ tons weight, furnished with projections or picks, fixed in a well-hole at midships, and worked by a chain attached to the paddle-shaft. On ascending a river the "grapin" is lowered till the picks grip the bed on which the wheel slowly turns, and the paddles working at the same time in this way tow barges over the strongest rapids. Huet's water locomotive and Busquet's tug are worthy of mention; the latter works on a chain, though it is similar to a wire-rope tug. The Baxter steamboat mentioned above as being in use on the Erie Canal, was the outcome of a competition invited by the State of New York for a prize of £20,000 for the steamer which best fulfilled the following conditions, viz. a mean speed of 3 miles an hour with a load of 200 tons, small cost, and no wash or swell. This steamboat is 100 feet long, 17½ feet wide, and about 9 feet deep, with flat bottom and vertical sides, and including engines and coal weighs 52 tons, carries a load of 200 tons, with a draught of 6 feet of water, and has an average speed of about 4 miles, but can work up to 7½ miles an hour.

On the Saar Coal Canal Jacquel's[1] steam-tug system is in use, where the screw is within the body of the vessel and surrounded by a cylinder, and is fed with water by two large channels leading from the sides of the vessel to the front of the screw.

W. H. E.

Distribution of Water from Irrigation-Canals. By M. Bricka.

(Annales des Ponts et Chaussées, 6th series, vol. iii., 1882, p. 503, 4 pl.)

This article indicates the importance of a careful system for the distribution of water for irrigation, as gathered from the experience of the Verdon Canal, a matter often overlooked in the construction of irrigation-works.

Irrigation in Provence not merely increases the return from the land, but also enables any crop to be cultivated where, failing a supply of water, wheat, olives, and almonds are almost the only

[1] Minutes of Proceedings Inst. C.E., vol. lxiv., pp. 418, 419.

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produce. The gross return, which formerly hardly exceeded from £6 10*s.* to £8 per acre, has been raised by irrigation to from £13 to £24 per acre, in meadow land, and from £16 to £32 for potatoes, affording a very large increase in the net profit, which was formerly only about £1 12*s.* an acre. The profit in small holdings, from the culture of fruit and vegetables, is still larger. The water is generally supplied from April to September, over the whole surface for grass crops, and in channels for fruit and vegetables. It has been found in practice that a supply equivalent to 5⅓ gallons per minute per acre is sufficient; it is distributed periodically, the interval between the commencement of two successive waterings having been fixed for the distributing channels of the Verdon Canal at six days and a quarter, so that each proprietor may have his fair turn of day and night supervision. The rate of discharge which has been found suitable, so that, without undue expenditure of time in delivery, the supply may not exceed what can be properly distributed by the proprietor, is between 400 and 530 gallons per minute, and the quantity supplied to different properties is regulated by a variation, not of the rate of discharge, but of the period of flow.

The Verdon Canal has been previously described;[1] and the Author confines himself to a description of the distributing channels which bring the water to the head of the estate of each subscriber, and which were constructed by the same company who had the concession for the Verdon Canal. There are about 15 miles of these channels to every 1,000 acres. As economy is essential in forming the distributing channels, they have to follow the surface of the country, and to avoid severance; and the constructive works have to be restricted to falls, and crossings of unimportant roads and streams. The channels are accordingly very irregular, both in direction and slope; and numerous falls connect abrupt changes of level. Where a hard stratum exists near the surface, the amount of slope given to the channel is immaterial; but in a bed liable to scour, the rate of flow must not exceed from 2 feet 3 inches to 2 feet 8 inches per second. The flow, however, must not be less than 1 foot per second, otherwise the silt, which the water brings down in abundance after rain, or from the melting snows, would deposit and obstruct the channel. In places where it is inconvenient to replace a quick slope by a fall, scour has been prevented by dry rough pitching, resting upon a layer of broken stone, which impedes the undermining action of the current below the pitching. The section of the channels is generally flat-bottomed, with side slopes of 1 to 1; but sometimes through firm ground, and where scour is needed, the section is made rectangular. The works of construction, which are very numerous, consist of modifications, according to circumstances, of simple types, of which various specimens are given in the plates. The total cost of the 250 miles of distributing channels, in the

[1] Minutes of Proceedings Inst. C.E., vol. lxvi., p. 400.

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irrigated area of 18,530 acres in the Aix district, was about £29,600, or 1*s.* 4½*d.* per lineal yard.

The Author enters fully into the methods by which the construction and control of the distributing channels can be arranged, and shows the obstacles in the way of entrusting these matters to an association of the proprietors. If the State does not undertake it, the only other suitable authority is a company with a concession. It is impossible to estimate at the outset what the demand for water will amount to. Some soils, though apparently very dry, have a clay subsoil which retains moisture sufficient for good crops of wheat, and irrigation would only render the ground marshy. Small proprietors use a large quantity of water, as they irrigate all their land; whilst large proprietors rarely irrigate more than a third. Also the change of crops takes place slowly, so that at the commencement the demand for water is comparatively small. It is accordingly advisable not to extend the distributing channels till an adequate number of subscribers come forward. It is very important that the supply shall be delivered with great regularity, to prevent injury to the crops depending on it, and that no waste should occur. This is most effectually secured by entrusting the management of the sluice gates to responsible persons, not interested in the irrigation, who distribute the water according to regulations arranged each year, and who also are on the watch to prevent fraudulent misappropriation of the supply. Under these circumstances, the cost of allotment in a year amounts roughly to between 29*s.* and 47*s.* per gallon of water distributed per second; and the cost of maintenance, exclusive of large repairs, may vary from 20*s.* to 34*s.* for distributing channels situated in conditions similar to those of the Verdon canal.

L. V. H.

The Bursting of the Habra Dam in the Province of Oran, Algeria. By G. Crugnola.

(L'Ingegneria civile e le Arti industriali, vol. viii., 1882, p. 49.)

This dam, 1,060 feet long on the crest, and 116 feet high, retaining a volume of 1,050 million cubic feet of water, burst in December 1881, when the water destroyed several villages and part of the city of Perregaux, situated 6¼ miles down the valley. The number of victims of the catastrophe could not be ascertained, but two hundred and nine corpses were found on the plain of the Habra when the water subsided. The reservoir is said to have been by far the largest yet constructed.[1] It was originally intended that the dam should be of earthwork, but owing to the failure of two such dams of much smaller dimensions in the pro-

[1] The construction of the dam is described at length in the Minutes of Proceedings, vols. xli., p. 248, and liii., p. 325.

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vince, it was decided to build it of masonry. A section of the wall is given; it is 14 feet thick at top water-level and for 20 feet below it; from this point it has a batter of 0·6 to 1 on the dry, and 0·04 to 1 on the wetted face; there is a bench 12 feet 6 inches wide, at a height of 10 feet from the bottom on the dry side, and the bottom width (the height being 115 feet) is 105 feet. There is a parapet, 5 feet thick and 8 feet high, along the top of the dam. The Author considers that, from a theoretical point of view, this section is perfect.

The work was commenced in 1866, and finished in 1871. The dam was founded upon calcareous sandstone of the tertiary formation, which was of varying consistency. Some of the beds were of considerable thickness, others were thin, alternating with beds of clay, which in some places had to be dug out to a great depth and filled in with concrete. The sandstone was inclined at an angle of 30°, and rested, at an angle of 45° (with slope towards the valley), upon argillaceous schist of the secondary period.

The materials of which the wall was composed were found in the neighbourhood, and though stone, lime and sand, of fair quality were available, it seems doubtful whether sufficient care was exercised in their selection. The wall was by no means water-tight; but as soon as the water in the reservoir attained a depth of 30 feet, it began to show itself on the down-stream side of the dam, and, as the depth of water increased, the appearance of the wall was similar to that of a huge filter.

Just before the rupture of the dam a rainfall of 6¼ inches occurred in a very short time; the gathering ground of the reservoir was 800 million square metres, and the flood thus produced, coming down at the rate of 5,000 cubic metres per second, swept over the top of the parapet in a stream 1 metre deep, forming an immense cascade as it poured over.

The effect of this rush of water was to expose the wall to a strain more than double that to which it was subjected when the water was simply standing at its highest level in the reservoir.

W. H. T.

Improvement of Richmond-Island Harbour, Maine.

(Report of the Chief of Engineers, U.S. Army, 1881. Part I., p. 489.)

This refuge harbour is formed by a breakwater of rubble stone, 2,000 feet long, connecting the island with the mainland. The breakwater has an average thickness of 30 feet, and is raised 10 feet above mean low water. It was commenced in 1872, and has cost up to the present time about £22,600, the amount of rubble stone deposited being 66,400 tons. The final deposit of 2,000 tons, at 5*s.* 3*d.* per ton, was to be completed in September 1881. The harbour is available for the largest class of vessels, and, though open to the south-west, it affords shelter from the

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north and east, the quarters whence the most violent storms come, and it serves as a refuge for vessels prevented by these storms from entering Portland Harbour 12 miles to the east.

L. V. H.

Improvement of Rockland Harbour, Maine.

(Report of the Chief of Engineers, U.S. Army, 1881. Part I., p. 464, 1 pl.)

This harbour is formed by a bay, which is open to the east, but sheltered from other points. The improvement, now in course of execution, consists in affording shelter from the east by two breakwaters. One breakwater starts from Jameson Point, at the north-eastern extremity of the bay, and is to be carried in a southerly direction for a distance of 1,900 feet. This breakwater was commenced in April 1881; 13,000 tons of rubble stone had been deposited by the end of June, completing a length of 560 feet; and it was anticipated that the whole of the 24,000 tons forming the first contract would be in place by the end of November, at a cost of 3*s.* a ton. The second breakwater, which has not yet been commenced, is to be detached from the shore, and 2,640 feet long, going nearly due north and south. Its site is to the south-west of the other, and it is to stretch from a shoal called South Ledge, to a point slightly to the south of west from the end of the Jameson Point breakwater. There will, accordingly, be an opening between the southern end of the shore breakwater and the northern end of the detached breakwater, pointing a little to the east of south, in which direction the harbour is well protected by a projecting headland. This opening is designed to have a width of 1,300 feet. The breakwater in progress consists of a rubble mound, raised 5 feet above mean low water, 10 feet wide at the top, and with slopes of 1 to 1 on the inner side, and 2 to 1 on the sea side; its extremity will reach a depth of 26 feet at low water. The original design, of 20 feet width at the top, raised 15 feet above low water, was reduced, partly for the sake of economy, and partly as being an excessive section; and as it was considered that, when actual experience had been gained of the force of the ground swell, and of the shelter afforded, the section could be increased, and the breakwater raised if necessary. The estimated cost of the breakwaters is as follows:—

	£.
Breakwater from Jameson Point—135,000 tons of rubble stone at 3*s.* 3½*d.*	22,200
Detached breakwater—420,000 tons of rubble stone at 3*s.* 3½*d.*	69,100
Engineering and incidental expenses, say . . .	11,500
Total	102,800

The works are to be carried out with such expedition as the grants allotted by Congress may permit. The proposed section of

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the detached breakwater is similar to the other, but the depth of water along the site amounts to between 26 and 40 feet. It is intended to commence this breakwater at its northern end, the one nearest the extremity of the other, so that the sheltered area may be increased in proportion to the extension of the breakwater.

L. V. H.

Improvement of Newbury-Port Harbour, Massachusetts.

(Report of the Chief of Engineers, U.S. Army, 1881. Part I., p. 501, 1 pl.)

This harbour, on the Atlantic, at the mouth of the Merrimac river, has its entrance impeded by a bar. The channel across this bar has been gradually shifting northwards, whilst great changes have taken place in the projecting beaches north and south of the entrance. The depths, however, seawards have not varied, and the minimum depth over the bar, at mean low water, which was 6 feet in 1851, was 7 feet in 1878, and 7½ feet in 1880, with an average rise of tide of 7½ feet. The bar consists of soft mud and loose sand overlying coarse sand and fine gravel. It was decided in 1880 to fix the channel, and to secure a depth of 13½ feet at low water over the bar by means of two converging rubble stone jetties built out from the shore, north and south of the entrance, and leaving an opening of 1,000 feet between their extremities. The jetties are to be 15 feet wide at the top, raised 4 feet above mean high water, and with inside slopes of 1 to 1, and sea slopes of 2 to 1. Their estimated cost, including protective works at the northern end of Plum Island to preserve it from scour, is as follows:—

	£.
North Jetty, 170,000 tons of rubble stone at 5*s.* 5*d.* .	46,100
South Jetty and works on Plum Island, 80,000 tons at 5*s.* 5*d.*	21,700
Engineering and contingencies, say	7,200
	75,000

A contract was made at the end of 1880 for commencing the deposit of stone in the northern jetty at a cost of 3*s.* 5*d.* per ton; but the cost of stone and freight increased so suddenly that the contractor was compelled to relinquish the work. After some difficulty and delay a contract was obtained, in the middle of 1881, for the deposit of 60,000 tons of stone at 5*s.* 5*d.* per ton, which was to be completed in 1882. It was proposed to expend about £20,500 in 1882–83, which, with previous expenditures, would leave an estimated balance of cost for completing the work of £36,000.

L. V. H.

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On the Preparatory Works of the Submarine Railway between England and France, and the geological conditions in which they are carried on. By M. DAUBRÉE.

(Comptes-rendus de l'Académie des Sciences, Paris, vol. xciv., 1882, p. 1678.)

During 1875 and 1876 a geological study was made both on the English and French sides, comprising an exact contour of the bed of the Straits, and borings on land, to find out the nature, thickness, inclination, and bearings of the strata, from which an approximate idea was formed as to whether they were impervious or not to water. Since 1879 experiments have been made on galleries of small section, and on the machines and tools likely to be called into requisition in a work of such exceptional importance. The geological survey showed that the strike of the strata, which is N.N.E. at the Straits, becomes S.E. at the Cliff of Blanc-Nez, the dip being 50 millimetres to the metre at the former, and 90 millimetres to the metre at the latter place, it became necessary to find how far this affected the bed of Rouen chalk. With this object in view, two borings were made of a depth of 86 metres, and gault was found at a depth of 59 metres below the hydrographic zero (*i.e.* the lowest tide at Calais). These borings proved that all the white chalk and the upper portion of the Rouen chalk were water-bearing. In one the water poured in at the rate of 7,500 litres a minute. On the other hand, the lower portion of the Rouen chalk was found to be impervious, and thus peculiarly suitable for the tunnel, as the geological survey seemed to prove that it ran across from France to England without discontinuity or fracture. The water which found its way into the workings was soft and of good quality, although sometimes brackish; and, as the depth of water in the wells was affected by the tide, there was evident communication between the water-bearing strata and the sea.

On the English side a boring 47 metres in depth was made at Shakespeare Cliff, passing through the Rouen chalk; 15 metres situated above the sea, drained naturally, and the remaining depth of 32 metres was found absolutely impervious. At the bottom of the boring, 29 metres below the French zero, a gallery has been commenced below the sea, following the bed at a descending gradient of 12·5 millimetres to the metre. Colonel Beaumont's apparatus is used on both sides, and with its aid a perfectly cylindrical gallery, 1,800 metres long, and running for 1,400 metres beneath the sea, has been made from the English side; in the whole of this length there has been no inflow of water. The rock has been found quite dry, and even produces powder under the blows of the tools. The water, wherever found, has come from small fissures in the rock, but the apparatus employed entirely stops these leaks. This is effected by a cast-iron casing formed of rings, whose external diameter is exactly the

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internal diameter of the gallery. The rings are divided into five segments, strengthened by ten ribs, through which pass bolts, which unite the segments and rings; the four segments are first put in, and the fifth keys the whole. Where the water runs in with some velocity a cement of red lead is used, which is placed between the segments and the rock, and forms a water-joint by the pressure of the rings against the rock.

E. F. B.

The Water-Supply of the Industrial District of Upper Silesia.

By B. Salbach.

(Journal für Gasbeleuchtung und Wasserversorgung, July 1882, p. 491.)

The district treated of comprises the towns of Beuthen, Königshütte, Kattowitz, and others; and the industry consists almost exclusively of mining operations, which for several decades have suffered considerably from the want of good water. The coal measures are here overlaid by strata of dolomite and sandstone, through which the rainfall penetrates, and collects in the numerous pits and mines, from whence it is pumped as non-potable pit-water.

In consequence of complaints made during the last ten years, the Prussian Government in 1873 commissioned Engineer Veitmeyer to report on the condition of the water-supply, who found the well-water of the district to be impure and insufficient for drinking purposes, and the pit-water of so hard and acid a character as to rapidly deteriorate boilers and create danger of explosion. The Author commenced his survey of the district in 1878, and found the requirements of the population to be 28,675 cubic metres[1] per diem for domestic, and 35,990 cubic metres for industrial purposes; making together 64,665 cubic metres, which quantity he considers should be increased to 70,000 cubic metres,[2] in view of the expected increase in the industrial demand.

In seeking a suitable source from whence to obtain the necessary supply, attention was first directed to the rivers of the district. They are the Przemsa, the Brinitza, and the Klodnitz. Of these, the water of the Klodnitz was found, by analysis, to be unsuitable. The withdrawal of so large a quantity of water from the Przemsa would, during the dry months of the year, endanger the navigability of the river, and the Brinitza could not supply the quantity required. The conditions of the soil and the number of pits and mines rendered it impossible to obtain the water from the upper

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[1] 1 cubic metre = 176·5 gallons.

[2] The Author allows 150 litres = 33 gallons per head for domestic purposes, but he does not state the quantity per head for industrial purposes, nor the population of the district.

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strata; but, although these yield no water, it collects in considerable quantity at a greater depth in the New Red Sandstone, which is here covered by a stratum of red clay. Borings made down through the clay at the northern side of the district resulted in artesian springs, which overflowed the surface. The basin in which this water collects extends in a westerly direction, and meets at Peiskretscham, another basin coming from the north; the two basins join, and, widened out and flattened, continue on together in a southerly direction. Three borings made between 1873 and 1875, two of which pierced the New Red Sandstone, yielded together 12,000 cubic metres per diem. The water possessed a temperature of 10·75° Centigrade, and analyses showed it to be of excellent quality for drinking and other purposes.

After the construction of these wells a scheme was proposed for supplying the domestic requirements of the people with well-water, and the industrial establishment with river water, filtered and clarified. This project became further modified by the discovery in 1880 of a new source of supply in the springs of the Friedrich's mine, near Tarnowitz.[1] The water flowed out of a deep heading in the side of the hill in a considerable stream, and was found to be chemically pure, and to possess a uniform temperature of 9° Centigrade. The circumstances rendered it unnecessary to intercept the stream at the mouth of the heading, inasmuch as the springs collect together at the bottom of the down-shaft, called Glückhilfschacht, and are by the time they arrive there sufficiently clear and pure to admit of the water being pumped direct from the shaft itself. The quantity of water thus rendered available was found to be 36,000 cubic metres per diem, and thus the use of river water was rendered unnecessary.

The scheme became therefore amended, and it was proposed finally to have one service only, supplied conjointly from artesian wells at Zawada, near Peiskretscham, and from the Friedrichsgrube, near Tarnowitz. The necessity for an experimental boring at Zawada was imperative, and was commenced in September 1880, on receipt of permission from the government. The work consisted of, first, the construction of a basin at the head of the well, 5 metres in diameter, and 2½ metres deep, having a weir and conduit at one side, by which the water that should rise from the boring might be measured and carried off. Subsequently a second weir was constructed, because the quantity and force of the water was such as to prevent a correct measurement over one weir only. The boring was commenced in the centre of the basin with a diameter of 74 centimetres (28¾ inches), but on reaching a depth of 43 metres the diameter was reduced to 55 centimetres (21½ inches), on account of two faults filled with clay, in which limestones were embedded, which crossed the boring diagonally. The work was much delayed by these faults, as in crossing the second

[1] Tarnowitz is situated at the north-east corner of the district.

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of them the tube became bent, and had to be withdrawn and replaced by a new one. On getting past the faults the boring entered solid limestone, in which the insertion of a tube was unnecessary. The work then proceeded without interruption from June 1, 1881, till October 3, when the red clay overlying the New Red Sandstone was reached at a depth of 177 metres. Water in small quantity appeared at 3½ metres beneath the surface. At a depth of 111 metres, on leaving the blue clay and entering a stratum of porous limestone, the water began to rise in the boring; and at 120 metres it overflowed the surface at the rate of 2,200 cubic metres in twenty-four hours. The yield of water increased as the boring attained a greater depth. At 136 metres a sudden increase took place, the quantity then delivered being 8,700 cubic metres; and another sudden increase, at a depth of 150 metres, raised the quantity to 12,000 cubic metres per diem. At 177 metres the quantity overflowing at the surface was 14,870 cubic metres per diem. The water was perfectly clear, and possessed a temperature of 11° Centigrade.

The old borings, at a distance of 500 metres away, showed a reduced yield of water in proportion to the increase at the new boring; on reaching 136 metres their yield was diminished from 12,000 to 4,800 cubic metres, and at 177 metres depth it amounted only to 3,000 cubic metres per diem. On entering the red clay a tube of 44 centimetres diameter (17 inches) was inserted. At 190·5 metres the New Red Sandstone formation was reached, the first 8 to 10 metres of which consisted of loose sand. The boring was, however, continued with the insertion of a tube of 25, and and afterwards of 15 centimetres diameter (9¾ and 5¾ inches) to a total depth of 215 metres, when, no increase in the yield of water being observed, the work was concluded, and the last 10 metres were filled with coarse gravel to prevent the sand from rising and blocking the boring.

From measurements made after the cessation of boring, it was found that the upper water level stood at about 4·8 metres above the surface of the ground, and that if 30,000 cubic metres per diem were pumped from the well, the water-level would sink to 8·3 metres below the surface. The construction of a pumping well 12 metres deep is therefore recommended, in which the pumps shall reach to a depth of 10 metres (32·80 feet), and that the boring be widened to 75 centimetres diameter down to the red clay. Analyses of the water made by Dr. Hulwa, of Breslau, give the most satisfactory results, the hardness varying from 10·92 to 13·6 German degrees.

From the Friedrichsgrube, after driving a heading northwards and thereby tapping the works north of Tarnowitz, a total quantity of water equal to 23,040 cubic metres per diem may be obtained,[1] but the water contains white flocculent organisms, which are how-

[1] The former quantity quoted, viz. 36,000 gallons, became reduced during the dry seasons following the discovery of the springs.

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ever of local origin, and can be prevented from mixing with the general supply.

The Author then enters into a detailed statement of the quantity of water required daily by the different townships and colonies in the district, and the proportion to be supplied from each of the two sources, and then describes the general scheme submitted in the report as follows. It is proposed to supply the north and north-east portion of the district from the Friedrichsgrube source by a pumping station situated at Glückhilfschacht, and a delivermain of 50 centimetres diameter (19½ inches), which, following the line of the Upper Silesian railway, and afterwards the highway between Tarnowitz, Beuthen and Königsgrube, ends at the last-named town, where a water tower and service reservoir of 1,000 cubic metres capacity is to be constructed. The water-level in the reservoir will be 15 metres above the level of the highest point of supply. The west, south, and south-east portions of the district are to be supplied from the artesian well at Zawada, where pumping engines capable of delivering 30,000 cubic metres per diem are to be erected. Duplicate and parallel leading mains, of 55 centimetres each, are to conduct the water as far as Donnershütte (about 10 English miles), where dividing, they will encircle the western division, and afterwards unite in one main of 70 centimetres (27 inches) diameter. This main will terminate at Carl Emmanuel colony in a reservoir of 25,000 cubic metres capacity. A main of 60, diminished to 40, and then to 30 centimetres diameter, will carry the supply on to the southern and south-eastern divisions. After further development of the district, a second set of pumps and another leading main are to be erected at Glückhilfschacht, the main passing through Bobrek (at first supplied by a branch from Beuthen) and joining that from Zawada at Ruda. Other branch supplies are to be carried out as occasion requires; and for the township of Antonienhütte, which is separated from the general system by a hill, a separate reservoir of 2,000 cubic metres capacity is to be constructed on the hill-side, and the water pumped up by a small engine from the larger reservoir at Carl Emmanuel colony.

The description of the scheme is accompanied by a map of the district, showing the positions of the pumping stations and the mains and reservoirs. The whole district comprises an area of about 200 English square miles, and includes seven towns, besides numerous mining colonies, the population of which is not stated in the Paper.

The Author gives the following estimate of the cost of the proposed works:—

	Marks.
The Friedrichsgrube system, 1st portion	1,384,000
The Zawada system, complete	5,000,000
The Friedrichsgrube, 2nd portion	1,120,000
Total	7,504,000

(Say £375,200.)

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The working expenses, average daily consumption, and cost of water per cubic metre, are given as follows:—

—	Working Expenses and 6 per cent. for interest and Amortisation.	Average Consumption per diem.	Cost Price of Water per Cubic Metre.
	Marks.	Cubic Metres.	Pfennige.[1]
Friedrichsgrube, 1st part . . .	136,640	8,000	4·68
Zawada system	415,000	25,000	4·55
Friedrichsgrube, 2nd part . . .	117,200	11,520	2·79
Total. . . .	668,840	44,520	4·12

A Map of the district accompanies the Paper.

G. E. S.

Antwerp Waterworks. By — DE ROUBAIX.

(Bulletin de l'Association des Ingénieurs sortis de l'École de Liége, July and August 1882, p. 135.)

The water for the supply of the town of Antwerp is drawn from the river Nèthe, at the Waelhem bridge, 10½ miles south of the town. The water, after having been purified, is sent in pipes, under a pressure of five atmospheres, from Waelhem to Antwerp.

The process of purification consists: 1st, in allowing the water as it comes from the river to settle the solid matter, and then decanting the clean water; 2nd. Filtration through spongy iron and sand; 3rd. A second filtration through sand; 4th. The discharge of the purified water into the conduit.

The deposit from the water takes place in two basins alternately. These are filled three hours after each high-tide, when the water is in the best condition, by a 4-feet pipe from the river, passing through the embankment or dyke. Each basin holds 6,000 cubic metres (1,320,000 gallons), and is filled in three-quarters of an hour. The water remains in each basin for twelve hours, and is then run off from the surface into pits, whence it is lifted by means of screw-pumps to the level required for delivering it into the filters.

There are two elevating screws, 40 feet long, and 3 feet in diameter, placed at an angle of 30°, driven each by a 12-HP. engine. Each screw delivers 9 cubic feet of water per revolution, and they have 80 per cent. of efficiency. There are three filter-beds of spongy-iron, placed side-by-side. The spongy-iron appears

[1] The pfennig = 0·1175 penny English.

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to be a bluish-grey scoria, of which the pores are much subdivided; it is in pieces of the size of hazel-nuts, prepared from a rich iron-ore. It holds in its pores a large quantity of air minutely divided, in presence of the oxygen of which the organic matters in the water are burned or oxidised, when the water passes away fresh. Each filter-bed consists of three layers. At the bottom, the first layer, 3 feet deep, is a mixture of three parts of spongy-iron and one part of pea-gravel; then a layer of fine gravel about 4 inches deep; and, at the top, a layer of sand from Dordrecht, 2 feet thick. The foundation consists of beds of brick, open laid, through which the filtered water passes into a collecting channel, by which it runs off to the sand-filters.

The sand-filters are three in number, one to each filter of spongy-iron, formed of three layers of sand and gravel. They detain pieces of iron-oxide that escape from the iron-filter, with the last impurities in suspension. The water, now fresh and pure, flows off into the reservoirs, which are circular and covered, and are constructed of cast-iron plates.

The pumping-engines for forcing the water through the mains were constructed by Messrs. Eastons and Anderson. They are in two pairs, compound, of 100 HP. each. The cylinders are 18 inches and 29½ inches in diameter, with strokes of 44 inches and 66 inches respectively, making, at maximum speed, twenty-two turns per minute. The pump delivers 48 gallons per revolution of the engine.

D. K. C.

Experiments made with the Deacon Waste-water-Meter System.

By Dexter Brackett.

(Journal of the Association of Engineering Societies (U.S.A.), vol. i., p. 253.)

The experiments described in this Paper were made upon the Boston Waterworks during 1881–82, for the purpose of checking the waste of water. The method adopted was the same as that in use in Liverpool.[1] The experimental district contained different classes of houses, but few shops or warehouses. The population was estimated at 21,760 persons, who were supplied by 3,170 stopcocks, or an average of 6·86 persons per stopcock. The inspections began on the 10th of May, 1881, and continued until the 18th of November. The district was divided into twelve sections, and the inspections in each section were made at intervals of two months. Before the inspections began, the average consumption in the district was 58·5 gallons per head per twenty-four hours, and the night rate 37·5 gallons per head per twenty-four hours. After two or three inspections had been made in each section the respective rates were 37·7 and 15·8 gallons. These results agree very closely

[1] Minutes of Proceedings Inst. C.E., vol. xlii., p. 129.

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with those obtained in Glasgow by the same method, and show that the wealthier classes are the largest consumers of water.[1] The conditions of supply in Boston and other American cities correspond more closely with those which exist in Glasgow than with those of any other European city.

The causes of waste were: 1. Defective services and fittings on the premises of the water-takers; 2. Defective mains and services on the premises of the city; 3. Wilful waste. A Table giving the details shows that there were seven hundred and ninety-four sources of waste discovered by the inspectors. The largest leak was on a wrought-iron service-pipe which was found wasting 1,000 gallons per hour. The waterclosets were the greatest sources of waste; three hundred and forty-three were found defective, twelve of which wasted 30,000 gallons per twenty-four hours. They were of bad design, and were supplied direct from the street mains. The defective mains and services on the premises of the city were generally in good repair. It was expected that many leaks would be found on the pipes laid when the works were constructed, fifteen years ago, as they were of wrought iron, coated inside and out with cement mortar, and had been partially replaced with cast-iron pipes. However, the leaks discovered were not of sufficient importance to warrant the expense of uncovering much of the main pipe. The whole waste from mains and services was not more than 300 gallons per hour. The wilful waste was due to one hundred and twenty-four waterclosets deliberately left running, and each wasting from 100 to 300 gallons per hour; and to people leaving taps open in cold weather to prevent the water freezing. A table and two diagrams show the amount of this waste in one of the sections; the advent of cold weather more than doubled the daily consumption in six days, while the night rate was increased from 9·2 to 52·3 gallons per head.

In all the annual reports of the water departments throughout the country, reference is made to the waste of water, and the best means for its prevention. A table giving the statistics regarding various American towns, shows that the consumption in many of them is about double that of their English brethren. Another table exhibits the results of measurements in various cities for the purpose of determining the consumption between 1 and 4 A.M. In Chicago, during 1880, the waste, assuming a legitimate use of 50 gallons per head, was 32,000,000 gallons. The yearly cost of fuel to pump this was £8,000. In Detroit, during the year 1881, the cost of pumping the waste water was two-thirds of the cost of pumping the whole supply.

With these data it is considered how much water is necessary for an ample supply. In Boston, in 1838, 28·5 gallons were considered sufficient; but taking into consideration the actual quantity consumed at present in large cities, engineers are providing for 60 to 70 gallons per head in new works. The Author is of opinion that

[1] Minutes of Proceedings Inst. C.E., vol. lxvi., p. 335.

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where the meter system or careful inspection prevails, 27 gallons per head is ample for domestic purposes, including the supply for stables, and for such shops as are necessary for the ordinary needs of a community. Adding the amounts required for all purposes, 50 gallons per head is sufficient for the largest cities in the country.

The methods for preventing waste are divided into three classes: house-to-house inspection; the application of water-meters to all the service-pipes; and the use of waste-detectors. The results obtained by house-to-house inspection in Boston and Cambridge are described. When the waterworks for Providence, Fall River, and Pawtucket were constructed, water-meters were fixed on most of the service-pipes, with the result that only 36·3 gallons per head is consumed in Providence, and 30·1 gallons in Fall River.

Boston has been the first city in America to adopt the waste-water-meter system, which is only a modification of house-to-house inspection. Neither of these two systems can be effective unless stringent regulations are enforced regarding the plumbing, similar to those introduced in Glasgow, Manchester, and other English cities. The meter system cannot be introduced upon old works except at great expense; for new works it affords the most satisfactory method of controlling the supply. The Deacon system can be introduced with good results only where the services are provided with stopcocks. As the conditions of supply in most American towns are different from those which exist in Liverpool, it is not probable that equally good results will be obtained.

The Paper is accompanied by numerous plates and tables.

T. S.

Jacquet's Piston Water-Meter. By A. Marnier.

(Revue Industrielle, August 30, 1882, p. 341.)

This meter has a piston packed with cupped leathers, working in a vertical cylinder, which is closed at bottom by a plain cover, and at top by the valve-chest bolted upon it. There are four mushroom valves, coupled together in pairs on horizontal stalks, and suitably controlling the alternate inlet and outlet ports for top and bottom of the cylinder; the two pairs are also coupled to a slotted cross-head, so that all four valves are reversed simultaneously by the rocking of a bell-crank lever, which is actuated at each reciprocation of the piston by a slotted piston-rod. The bell-crank is made with a knife-edge bearing, which is held up to its seat by a plate-spring stirrup, so hung as to rock with a longer radius than the bell-crank does.[1] The bell-crank's central position is consequently one of unstable equilibrium; and as soon as from

[1] For description of the same construction in Barton and West's piston water-meter, see Proceedings of the Institution of Mechanical Engineers, 1879, p. 444.

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either side this dead point has been reached through the piston's motion, the spring throws the bell-crank over to the opposite side, whereby the whole of the valves are reversed instantaneously. At each double reciprocation a pawl on the piston advances a ratchet-wheel through one tooth; and the measurement is indicated on dials in the usual way through a train of gearing.

Experiments made in Paris have shown the meter to be correct for a minimum flow of 1½ gallon in an hour; the loss of head was less than 5 inches. In regard to corrosion, a meter with ⅞-inch inlet-orifice, which, with 100 feet head, will measure up to 1,760 gallons per hour, was tested by filing down its knife-edge bearing; and it was found that a bearing of originally 0·9 inch depth had to be brought down to 0·7 inch depth, by filing off 0·2 inch of metal, before the working began to be at all impaired.

A. B.

Water-Gas. By Prof. Dr. von Marx.

(Zeitschrift des Vereines deutscher Ingenieure, vol. xxvi., 1882, p. 314.)

The introduction of gas-engines, and the extended use of gas for heating purposes, is causing considerable attention to be paid to the methods of manufacturing a special gas for the above purposes, that shall be produced at a cheaper rate than the ordinary lighting-gas.

Two such gases are generator-gas and water-gas. To produce generator-gas, fuel is subjected to incomplete combustion by which means the carbon unites with oxygen to form C O, which is afterwards burnt into $C O_2$. The great disadvantage of this process is that the carbonic oxide is mixed with about 70 per cent. of inert nitrogen, which makes the gas too bulky for economical conveyance through pipes. With water-gas the case is different. Here the oxygen is supplied to the fuel in the form of steam, when one, or both, of the two following reactions takes place:—

$$C+H_2O=H_2+CO \text{ or } C+2H_2O=2H_2+CO_2.$$

The first reaction takes place with a high temperature and an excess of carbon, the second by a lower temperature. In practice, however, a mixed gas is obtained. The first process is the more economical.

The Author traces the development of the manufacture of water-gas, and gives descriptions and illustrations of the principal systems that have been tried. In nearly all the modern plants that have been set up the use of retorts heated from without has been given up, and the heating and gas-making are now performed in the same chamber in alternate periods.

In the fundamental notion of water-gas there is no theoretical loss or gain, but only a change of the form of the fuel from a solid

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to a gaseous condition. Water-gas has more heating power than generator-gas, but less than an equal volume of lighting-gas. It can, however, be produced at a much cheaper rate than the latter, and from the poorest fuel. For lighting purposes it can be carburised by charging it with the vapour of light oils. Water-gas is highly poisonous, and almost inodorous. It has been proposed to mix it with strongly smelling vapour, in order to render its presence recognisable. The Author considers that under certain circumstances, and to a limited extent, water-gas may become the fuel of the future.

W. P.

The Danks Mechanical Stoker. By J. G. Danks.

(Scientific Proceedings of the Ohio Mechanics Institute, July 1882, p. 118.)

In the Danks mechanical stoker there are two grates; one vertical, about 12 inches high, the other horizontal, say 3 feet long. The vertical grate is movable on a hinge, and may be lowered so as to admit of the fire being conveniently kindled. With the additional surface of the vertical grate, the ordinary grate may be curtailed so as to be the more readily kept covered automatically with fuel. The furnace is fed with slack, by means of screws revolving in troughs which form part of the grate, the fresh fuel being carried into the furnace beneath the incandescent fuel. The combustible gases distilled from the fresh fuel are heated as they pass upwards to the surface, and quickly consumed.[1] The fire-grate is placed so as partly to project in front of the boiler, in a combustion-chamber of firebrick, where the gases are produced, heated, and ignited, before coming into contact with the boiler. A saving of 25 per cent. of fuel is claimed for this apparatus.

D. K. C.

Berlier's Pneumatic System of Scavenging.

(Nouvelles Annales de la Construction, vol. vii., July 1882, p. 97.)

The principal plans hitherto employed in Paris for the removal of sewage are considered. The system in common use involves the provision under each house of large permanent or fixed cesspools, having a capacity of from 25 to 30 cubic metres (882 to 1,059 cubic feet), in which the whole of the liquid and solid dejections remain for a period of from twelve to eighteen months, the contents being ultimately removed by processes all of which give rise to

[1] This system of propulsion is the same as that employed by Mr. M. Holroyd Smith, of Halifax, in his mechanical stoker.

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smells of an offensive character. The most usual mode of extracting the contents has been by means of exhausted receivers, the vacuum being created either at some central station or on the spot. In the latter case it becomes necessary to provide a steam-engine with a Koerting injector, or some apparatus of a similar kind. This machine was not only noisy, but unless the foul air from the receiver was burnt, or disinfected in some way, it occasioned a very bad smell in the neighbourhood. If the air is extracted at some central station, no bad smell and no noise arises, and all that is required is to fix to the vessel a length of well-jointed pipes connected with the cesspool, and the emptying takes place spontaneously by simple barometric pressure. This last system might, with trifling alterations, be carried out on a similar principle, without the intervention of vessels on wheels, or any disturbance of the cesspools. For all that would be necessary would be to lay down a network of pipes having connections with each cesspool, and provided with valves capable of being opened with a key, similar to those used by the water companies. By this means all the scavenging of a town could be managed from a station outside its boundaries, furnished with a service of exhaust pumps, and this plan is, in fact, that which Mr. Berlier has realised. By the use of gravitating sewers certain large towns, such as London, Brussels and Berlin, convey away at once all fecal matters, mixed with the domestic waste water of every description. This water-carriage system, though it has many advantages from a sanitary point of view, involves many conditions which are not always obtainable. 1st, The employment of a sufficiently large volume of water to carry away all the solids, and prevent deposits of all kinds in the sewers; and 2nd, A well-developed network of sewers all through the district, having a good fall, and communicating as little as possible with the atmosphere. For various reasons indicated, the sewers of Paris could not be employed for the convection of a mixture of the solid and liquid excreta. A mixed system, the division plan (*système diviseur*), has therefore been introduced into about one-fifth of the houses of Paris, to avert the dangers which might arise if solid matters were passed into the sewers, and partly, perhaps, in order to interfere as little as possible with existing customs. This system consists, in its essential parts, of movable tubs or pans, divided into two portions by a grating, which permits of the free passage of the liquids to the sewer, but retains all paper and solid matters. The objections to this system are that the liquids which contain seven-eighths of the putrescible elements escape into the sewers, together with much of the solid matter dissolved and washed down by the water used in the closets. Under the system invented by Mr. Berlier, the fecal matters are removed almost as fast as they are produced, and are transported to the depôt without contact with the atmosphere. His system, as already pointed out, is a natural extension of the pneumatic plan of scavenging now in use. The idea is, in fact, not original, having been proposed by Mr. Belgrand as far back as

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1861, and in accordance with the suggestion then made, that the Paris sewage should be pumped to Bondy, two passages were arranged in the main outfall sewer on the left bank of the Seine, which were respectively 0·40 metre (16 inches) and 0·30 metre (12 inches) in diameter. Mr. Belgrand's idea was never worked out; but Mr. Berlier, the director of the Lyons Sewage Company, after publishing a pamphlet explaining his plan, carried out an experiment on a considerable scale in Lyons, in 1880, and subsequently has been permitted to apply his system to the drainage of a district between Levallois-Perret and the Madeleine in Paris. The works for producing the vacuum are situated at Levallois-Perret, at the junction of two main sewers. The pipes are taken along the right bank main sewer as far as the Place de la Concorde, the length being about 5 kilometres (3·107 miles). In this length there are four siphons. The diameter of the pipe is 0·15 metre (6 inches), and the branches are carried out in pipes 0·10 metre (4 inches) in diameter. In pipes of the latter size, the sewage is now being collected from the barracks of the Rue de la Pépinière, which contain one thousand men. The arrangement of the apparatus is explained with reference to diagrams given. There are twenty receivers and eight evacuators. The receivers, which are rectangular in form and air-tight, are placed directly under the feet of the soil-pipes. In the interior of each receiver is a perforated basket, or grating, made of open ironwork, with wide meshes capable of retaining large foreign matters, but permitting liquids and solid fecal matters to pass through freely. The receiver is furnished with a manhole, or door, for the purpose of inspection, and the basket can be readily taken out for cleansing. It is so arranged that one half of it is always under water, in order to allow of the rapid solution of paper and other matters capable of being disintegrated. Moreover, by a simple arrangement of bevel gear, the basket can be made to partake readily of a rotary motion, for which purpose the shaft carrying the lower spur-wheel is furnished with a square head, to enable it to be moved with a key from without. The apparatus can in this way be freed from adherent paper and undissolved impurities. The evacuator is a cylindrical air-tight vessel, with a cone-shaped weighted float, the apex of the inserted cone being an india-rubber ball, which closes the outlet into the pipe. When there is sufficient liquid in the evacuator to raise the float, the aperture to the outlet valve is opened, and the liquid is sucked by the exhaust pipe to the depôt. When the liquid sinks to a certain level the float drops, and the valve is automatically closed. This operation is repeated as often as the liquid reaches the height necessary to raise the self-acting float. One similar apparatus suffices to discharge two, three, or even four receivers. The experiments carried out during three months in Paris have proved, first, that it is feasible to maintain a vacuum throughout a large network of cast-iron pipes. It is, in fact, possible in a few minutes to obtain a vacuum equivalent to a barometric height of 0·70 metre (27·5 inches); and second,

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that fecal matters, under the action of a vacuum, pass more freely through pipes than water, and that therefore the minimum fall of the Paris sewers will suffice for the establishment of a system of drainage on this plan.

With reference to the cost of this system, assuming the total length of the Paris sewers at 1,070,000 metres (664·8 miles), and the average cost of pneumatic piping at 25 francs (£1) per metre run, the expense of the pipes would be equal to 26,750,000 francs (£1,070,000). Three pumping stations at 1,000,000 francs each would cost 3,000,000 francs (£120,000), or say the total expense of dealing with Paris on this plan would be 30,000,000 francs (£1,200,000). By taxing each householder at 60 francs (£2 8s.) per annum for each soil-pipe, and assuming that the apparatus was attached to two hundred and forty thousand soil-pipes, there would be an annual income of 14,400,000 francs (£576,000). The annual expense of scavenging Paris on this system would, the Author estimates, be 4,400,000 francs (£176,000), leaving 10,000,000 francs (£400,000) to pay interest on the capital. In conclusion, the Author describes how the sewage water might be profitably employed for irrigation.

G. R. R.

On the Preparation of Smoke-poudrette at Landshut.

By A. von Podewils.

(Verhandlungen des internationalen Vereines gegen Vereinigung der Flüsse, des Bodens, und der Luft, 1880, p. 10.)

The process of converting human dejections, both liquid and solid, into a dry powder, which the Author had brought before the last meeting, has, he states, since then been practically tested by experiments on a large scale, at the town of Landshut in Bavaria. The works he had constructed were capable of treating the excreta of ten thousand persons daily, amounting to about 15 cubic metres (3,300 gallons). The two chief points to be attained in the manufacture of poudrette are the evaporation of the excessive volume of water and the preservation in the manure of all the valuable constituents of the excrements. Further, in order to be practicable, the process must be capable of being conducted at a profit, or in other words it must be carried out at the lowest possible expenditure of fuel, chemicals and labour. The Author's process consists in passing coal-smoke through the fecal matters by means of an air-blast. The manufacture can readily be conducted without interruption of any kind. The excrement, on leaving the smoking apparatus, is converted into a homogeneous, fluid compound, in which all the solid matters are dissolved and the kitchen refuse is mashed up. The fecal matters, moreover, have quite lost their disgusting character; the peculiar stench having disappeared, and a faint tarry smell only remaining.

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But the chief point is that on further evaporation after this smoking process no decomposition takes place, and there is no loss of ammonia, even if the compound is exposed to the direct heat of the fire. If, however, there was previous to treatment any evolution of free ammonia in consequence of the staleness of the liquid, all that is needed is a slight addition of sulphuric acid to fix the ammonia. Another important feature in this process is that the fecal matters are heated almost up to the boiling point by the passage of the smoke, and that the smoke, together with the gases evolved from the excreta, can then be burned in the furnaces employed to heat the evaporators. For final evaporation, the Author, following the plan of Liernur, makes use of three vacuum pans and a drying cylinder. The three pans work by triple effect. The steam from the third vessel is condensed with water into which it is drawn by means of an air-pump. It is found possible for each pound of fuel to evaporate six times its weight of water in the boiler, and by triple effect each equivalent of fuel vaporises twenty times its weight of water. One cubic metre of excrement can, by means of the entire plant, as at present arranged, be evaporated to dryness with 1 cwt. of coal, costing 1*s*. If each cubic metre contained only 1½ lb. of nitrogen (taken at the low price of 8*d*. per lb.), the value of the nitrogen recovered would thus pay the whole cost of the fuel. Fresh excrement contains, however, 22 lbs. of nitrogen, and, even with a considerable allowance for dilution with water and waste, the process can be carried on at a profit. For an establishment on the above scale two men only are required, and this staff could easily deal with a much larger quantity, even with the dejections of from fifteen thousand to eighteen thousand persons. Though the manure made in this way is slightly hygroscopic, the Author has found means to overcome this difficulty. It is of great importance that the works should be situated close to the town owing to the saving in cartage, which is the chief item of expense. There is very little objectionable smell to be perceived, either in the works themselves or in their immediate vicinity. The experimental manufactory has demonstrated first: that unless the excrement has lost the greater part of its nitrogen, either owing to putrefaction, or through excessive dilution with water, the preparation of smoke-poudrette can be profitably accomplished; and second, that there is no practical difficulty in regularly treating the excreta of the largest cities, even of those containing millions of inhabitants. The Author states, in conclusion, that he has made arrangements for dealing with the fecal matters of two important towns in Germany.

G. R. R.

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Ventilation of the Executive Mansion, Washington.

By WM. L. BAILIE, R. INCH, and W. S. MOORE.

(Annual Report of the Secretary of the U.S. Navy, 1881, p. 246.)

For cooling President Garfield's room and the adjoining corridor, during his illness in August and September 1881, two systems of apparatus were employed; one to deliver cool air directly into the President's room, and the other to deliver cool air into the corridor. For cooling the room, an apparatus designed by Mr. R. S. Jennings was tried. It consisted of a cast-iron box 27 inches square, 6½ feet in length, containing a number of "terry-cotton" screens on iron frames, placed longitudinally and vertically, ¼ inch apart. The box was surmounted by a galvanised iron tank of about 134 gallons in capacity, filled with a mixture of granulated ice and salt, in the proportion of 64 parts of cracked ice, 3 parts of salt, with 33 parts of water. This brine was delivered into a shallow pan, through which it percolated amongst the screens. Air was drawn into and through the box by means of a 14-inch Sturtevant blower, passing between and being cooled by contact with the screens. The apparatus was connected to the heating flue leading to the President's chamber.

The apparatus proved insufficient for the work of keeping the room cool, the windows being required to be open. An ice-box was added, through which the current from the screen-box was directed; and the effect was that a rapid and continuous supply of air at 55° Fahrenheit was maintained in the room. But, to counteract the effect of fresh breezes blowing directly into the room through the open windows, a 36-inch blower was substituted, and the current was reversed, being directed first through the ice-box, then through the screen-box, to the blower. The temperature was by this means maintained at the desired point during the extremely hot weather of 13th and 14th of August.

The first effect observed, even before the temperature was sensibly reduced, was a dryness of the air in the room, by which, in consequence of more rapid evaporation, the temperature of the skin was lowered. Whilst the humidity of the external air averaged 60, that of the air in the room, after passing through the cooling apparatus, averaged 54·3. During an experimental run of twenty hours, 8,734lbs. of ice were melted, being at the rate of 436·7 lbs. per hour, supplying 22,799 cubic feet of air at 50° Fahrenheit per hour.

D. K. C.

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Garlandat's Ventilator. By H. SCHWARTZ.

(Bulletin de la Société Industrielle de Mulhouse, April–May 1882, p. 150.)

Garlandat's ventilator is designed to supply moist air for the ventilation of large factories in which a humid atmosphere is required to be maintained. Air is blown into a cubical chamber made of iron plates, about 5 feet long, 3¼ feet wide, and 30 inches high. The air is delivered through the bottom, which is perforated with small holes for the greater part of its width, and is bordered at each side by a small channel or gutter, into one of which a constant stream of water is delivered. The water flows over the perforated surface, forming a stream of from ⅜ inch to ½ inch in depth, into the channel at the other side, whence it passes off and returns to the well from which it is lifted. The air forced through the perforated bottom passes upwards through the stratum of water overlying the bottom and absorbs a portion of it as moisture. Preliminarily, also, the air is moistened by being passed through the surplus water which returns to the pit. For this purpose a stratum of coke is formed within the well through which the water passes, and from which it falls in streams to the bottom. The air to supply the ventilator passes downwards with the water through the coke-bed, and mixes with the water as it descends, absorbing moisture at the same time, until, after having descended through a depth of 12 or 13 feet, the air arrives at the entrance of the suction-pipe, which is situated about 20 inches above the surface of the water in the mill.

The current of moistened air is conveyed in a sheet-iron conduit, 20 inches square, into the shed, which is traversed for its entire length by the conduit. The section of the conduit is diminished as it advances, the air being led off from it, right and left, by tin-plate pipes, 4 inches in diameter, from which the air is discharged through openings 1 centimetre, or 0·40 inch, in diameter, at intervals of 4 inches. In this manner, large volumes of fresh air are delivered without producing any sensible draughts.

In the instance described, of a spinning-mill all on the ground-level, the mill was about 70 yards wide and 12½ feet high to the spring of the roofing, having a cubic content equal to 26,400 cubic yards, in which one hundred and forty workmen were employed, and ninety at night, when, in addition, one hundred and forty gas-jets were burning. The quantity of air delivered was 13,300 cubic yards per hour, being at the rate of about 100 cubic yards per man per hour in the day, and 150 cubic yards per man per hour in the night. In August 1880 and July 1881, the temperature of the water on entering the apparatus was 57° Fahrenheit, and on leaving it 62½° Fahrenheit. The temperature of the air at the mill was 79° Fahrenheit, and on leaving the conduits 68°. The hair-hygrometer marked from 95° to 100° as the air left the conduits, corresponding to from 90 to 100 per cent. of humidity. The tem-

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perature in the shed was from 88° to 91½° Fahrenheit at 2 p.m., and from 86° to 95° Fahrenheit at midnight; and the humidity of the atmosphere of the shed was from 71 to 76 per cent.

D. K. C.

Trial of a Turbine at Immenstadt. By A. SEEMAN.

(Zeitschrift des Vereines deutscher Ingenieure, vol. xxvi., 1882, p. 301).

The turbine is worked with a fall of 181 metres (594 feet). The flow-pipe is 1·5 kilometre long (0·93 mile); the upper part consists of cast-iron pipes, 550 mm. diameter (21·7 inches), and the lower part of built up wrought-iron pipes, 480 mm. diameter (18·9 inches).

The turbine is an outward flow partial turbine, with horizontal shaft. The wheel is 2·72 metres diameter (8 feet 11 inches) outside, and 2·4 metres (7 feet 10½ inches) inside; the number of the vanes is one hundred and ten, and the breadth 120 mm. (4·7 inches) at the inside, and 400 mm. (15¾ inches) at the outside periphery. The water flows into the wheel through a single opening 110 mm. broad; the thickness of the jet is regulated by a slide, which can be worked by hand or coupled to an indirect-acting governor.

The whole plant cost about £17,870, of which the turbine itself, with foundations and shafting, cost £1,800, the rest being for the pipe-line, collecting reservoirs, drainage works, compensation, &c.

The turbine was tested by a brake placed directly on the turbine shaft. The water was measured by a notch bored in the tail-race. Braschmann's formula being specified to be used; this formula is—

$$Q = \left(0{\cdot}3838 + 0{\cdot}0386\,\frac{b}{B} + \frac{0{\cdot}00053}{h}\right) b\,h\,\sqrt{2g\,h},$$

where Q is the flow in cubic metres per second, b the breadth of notch, B the breadth of the rectangular channel behind the notch-board, and h the head above the bottom of the notch, all in metres.

The jet-velocity, as found by dividing the quantity of water by the area of opening, was 55,385 metres (181·6 feet) per second.

The efficiency was found to increase steadily with the amount of work done; for 82·5 HP. effective and two hundred and eleven revolutions per minute the efficiency was 0·595, and for 341 HP. effective and two hundred and ten revolutions, it rose to 0·764. The brake ran too hot to absorb the full power of 400 HP.; but the plotted curve gives 0·79 efficiency, which the Author thinks is a very satisfactory result, considering the very high jet-velocity.

W. P.

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On Recent Improvements in Gas-engines. By G. SACCHERI.

(L'Ingegneria civile e le Arti industriali, vol. viii., 1882, p. 22.)

This Paper gives notices of the gas-engines exhibited at the Paris Electrical Exhibition and the Milan Exhibition, as well as one of more recent invention, the Benier gas-engine. The principal Otto engine at Paris was of 50 HP., driving sixteen Gramme machines. This engine has two cylinders, or rather there are two single-cylinder engines; in one cylinder the mixture of gas and air is drawn in and compressed, in the other it expands, and the products of combustion are discharged. In this manner gas-engines of great power and very regular movement are obtained. Two 50-HP. engines have been erected in the theatre at Frankfort for driving pumps capable of raising 300,000 litres of water to a height of 60 metres. The quantity of water required is 40,000 litres per day. One engine is kept running empty during performances, so that the pumps can be set in motion in a few seconds. The consumption of gas when both engines are working at their full power is, according to Messrs. Langton and Woolf, 72 cubic metres of gas per hour; and when an engine is working empty, 5 cubic metres. The price of a single 50 HP. engine is about £880.

After referring to the Clerk and Bisschof's engines, the Author gives a short description of Ravel's, which was not known previous to the Electric Exhibition. It has a vertical oscillating cylinder, and its distinguishing feature is the method of introducing the explosive mixture. The gas and air enter a chest in the proportion of 1 to 10, the former through a narrow slit, the latter through a series of small tubes; they then mix together, pass through holes in the side of the chest, and onwards through a grating which leads to the bottom of the driving cylinder. The explosive mixture begins to enter the cylinder when the piston is at the end of its stroke at the bottom of the cylinder, goes on during one-fourth of the stroke, and is then shut off, but not till the explosion has taken place. Two indicator diagrams are given, one taken from a 1 HP., the other from a 2 HP. engine. The curve of pressure is very regular, the coefficients of efficiency being about 70 per cent. From 40 to 50 litres of water per hour are required to cool the cylinder; the consumption of gas is about 1 cubic metre per HP. per hour.

The Benier engine is very small and compact, and is intended for domestic use. With the exception of the piston-rod, its connection with the fly-wheel, and the fly-wheel itself, the whole is enclosed in a box. It can be taken to pieces to be cleaned, and put together again with great ease. The driving-axle is placed above and at right angles to the axis of the cylinder, which is horizontal. The box is filled with water, which surrounds the cylinder, and does not require renewal, it being kept cool by

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means of a series of vertical tubes, through which a current of air constantly passes. These engines are made in five sizes, of from 3 to 75 kilogrammetres power. They are said to consume from 250 to 1,200 litres of gas per hour, and to cost from £14 to £60.

The last engine mentioned is Faccioli's, which is somewhat similar to Otto's, but is double-acting, which increases the power of the engine while reducing the cost by about one-third.

W. H. T.

Experiments on a Benier Gas-engine of One-third HP. (nominal).

By A. Bottiglia.

(L'Ingegneria civile e le Arti industriali, vol. viii., 1882, p. 87.)

This engine having been already described in the "Ingengeria Civile" of February of the present year,[1] the Author now gives the results of his experiments for the determination of—

(*a.*) The conduct of the motive mixture in the cylinder;
(*b.*) The consumption of gas in relation to the power developed;
(*c.*) The coefficient of efficiency;
(*d.*) The means of obtaining the best results from the motor.

The Author lays down the following points as essential for a satisfactory motor:—Minimum cost; 2. Minimum, or, if possible, no cost of erection; 3. Maximum of simplicity, so that the taking to pieces and putting together for cleaning (which should be seldom required) may be quick and easy; 4. Solidity combined with lightness and smoothness; 5. Not to require the assistance of a mechanic; 6. To be capable of being started and stopped almost instantaneously; 7. Regularity of action, and the smallest consumption of combustibles, and this only during the time the machine is actually at work, and in proportion to the work done; and he considers that the Benier engine satisfies these conditions.

The Author describes his method of experimenting, gives some indicator diagrams taken from the machine, and some conclusions which he draws from them. It sometimes happens that the gas fails to explode during the stroke of the piston, or does so at a wrong period; the effect of this is not only that the work done by a given volume of gas varies, but also that the effect of the explosion is lost, and the piston on the return stroke is retarded by the gas in the cylinder. The consumption of gas per HP. diminishes as the power of the engine increases, and when working at its full power of one-third HP. the consumption is at the rate of 4 cubic metres per HP. per hour. The coefficient of efficiency is about 70 per cent.

W. H. T.

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[1] *Ante* p. 469.

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Study of Solar Apparatus. By A. Crova.

(Comptes-rendus de l'Académie des Sciences, Paris, vol. xciv., 1882, p. 943.)

The best known apparatus for concentrating the sun's radiant energy and converting it into sensible heat is that due to Mr. Mouchot, whose construction has been perfected by Mr. A. Pifre. Two commissions have been appointed by the Minister of Public Works to make experiments on two identical mirrors of 5·22 square metres, and to report on their practical bearing. The following is a succinct *resumé* of the Montpellier Commission:—

The experiments were carried on from the 1st of January to the 31st of December, 1881, and made from hour to hour every day during which observations have been possible. The solar rays, concentrated in the focal line of the mirror, were received on a blackened boiler, which occupied its axis, and which was surrounded by a cylinder of glass. The water boiled, and its vapour was condensed in a worm cooled by a current of water; the amount of condensed water shows the number of heat-units utilised by the apparatus to be calculated according to Regnault's formulæ. By means of actinometric observations, made from hour to hour, the number of incident rays were calculated; the temperature of the air, its hygrometric state, and the sun's heat were measured at the same time, which permitted the atmospheric depth traversed to be calculated by Laplace's formula. The following are the principal results obtained during one hundred and seventy-six days, which allowed of nine hundred and thirty observations being made, during which 2,725 litres (about 600 gallons) of water were distilled—

	Calories. Mean.	Calories. Maximum.
Heat directly received per square metre per hour	616·1	945·0
Heat utilised by the apparatus	258·8	547·5
Mean of efficiency	0·491	0·854

The efficiency is not proportional to the calorific intensity of the solar rays, and hardly ever varies in the same direction. The maximum of radiation took place, in fact, at Montpellier in the spring when the air is most dry, and has the greatest calorific transparency. The absolute quantity of heat utilised depends, on the contrary, essentially on the temperature of the air; the higher this is, that is, the lower the fall of temperature, the less is the effect of cooling, and the more considerable is the heat utilised. The maximum efficiency generally corresponds to the minimum intensity of the rays; with the greatest intensity the obscure rays, which glass does not transmit, are arrested by the cylinder, and the efficiency diminishes although the quantity of heat utilised is increased. The contrary takes place when the incident rays are much weakened by their transmission through an atmosphere of low calorific transparency, which stops the rays having great wave-length, and transmits those which only

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undergo a very small loss in their passage through the cylinder surrounding the boiler. Under the most favourable circumstances, assuming an incident radiation of 1,200 calories per square metre per hour, and an efficiency of 0·8, 960 calories would be utilised; this number represents the heat produced by 240 grams of carbon, assuming the efficiency of the boiler to be 0·5. In temperate climates the half of the above quantities cannot be depended upon, and the sun does not shine with sufficient regularity to utilise his rays in the manner contemplated. In very dry and hot climates, the possibility of utilising them depends on such circumstances as the price and facility of transport of solid fuel.

E. F. B.

On the Efficiencies of the Steam-Boiler and on the Conditions of Maximum Economy. By R. H. THURSTON.

(Journal of the Franklin Institute, vol. lxxxiv., 1882, p. 13.)

Let E denote the theoretical evaporative power, and E_1 the probable actual evaporative power of 1 lb. of fuel; let S be the number of square feet of heating surface per square foot of grate surface, and F the number of lbs. of fuel burnt in a given time per square foot of grate surface. Then, with Rankine, it may be stated that

$$E' = \frac{B E}{1 + \frac{A F'}{S}},$$

where A and B are coefficients. For bituminous coal Rankine found A equal to 0·3 to 0·5, and B equal to 0·9 to 1. The Author has made experiments with anthracite coal, and finds A equal to 0·3 to 0·5, and B equal to 0·8 to 0·9.

A given amount of steam being demanded, it may be obtained from a small extravagant boiler, or from a large economical one. In every case there will be a definite size of boiler, which will supply the steam at the lowest cost. Let the total cost of fuel per annum and per lb. burnt per hour on the square foot of grate be called C; let the total cost of boiler per square foot of heating surface be called D; and let $\frac{C}{D} = R$. The Author shows that the most commercially economical boiler to erect is one where

$$S = F \sqrt{A R}.$$

This proves that, *cæteris paribus*, the best area of heating surface will vary nearly as the square root of the total working time per annum.

A second commercial problem may be presented to the engineer.

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A steam boiler is in place, all expenses and their method of variation are known, to determine that rate of combustion which will yield most steam per dollar expended in producing it. For this case let K represent that total annual expense which is unaffected by change in the boiler proportions, or the amount of fuel burnt, such as nearly all, or frequently all, the costs of attendance; and let $K = \frac{K}{G}$, where G is the area of grate. The Author finds that the most economical amount of fuel to burn per square foot of grate is

$$F_1 = \sqrt{\frac{K S + D S^2}{A C}}.$$

If in the above expression K is made = 0, then the previous expression $S = F\sqrt{A R}$ is obtained, as obviously should be the case.

W. P.

The Test and Choice of Lubricants based upon a Mechanical Method of Testing. By R. JÄHNS.

(Organ für die Fortschritte des Eisenbahnwesens, vol. xix., 1882, p. 131.)

In testing a lubricant the two following conditions should be fulfilled:—

(1.) That the particular lubricant possesses those qualities necessary to reduce the friction, between two metal surfaces, to a sufficient degree for the purpose required.

(2.) That the particular lubricant has the power to resist, for a sufficient period of time, the destructive action of the work which it has to perform in its application.

Under the term "work" which the lubricant has to perform in the last condition, is understood the overcoming of the resistance of cohesion in the layer of lubricant between the two metal surfaces. This work not only produces heat, but also changes the chemical affinity of the constituents of the lubricant, and destroys and produces changes in their physical properties. The lubricant between the two metal surfaces is subject to no other action than this, and it must therefore appear advisable to base the test of the powers of resistance or endurance upon the examination of this action. Mechanical means must be preferred to the chemical tests generally employed, because the results of the former discover the effect of the action of all that takes place in the lubricant, which could not be perceived or followed by the chemical method alone. The Author remarks that lubricants are still, in very many cases, solely judged and compared by their behaviour in practice, and that this method only gives results, after a period of weeks or months, which are not even then reliable, as a regular and complete inspection cannot continually be made of the subjects of the test, whilst other factors, such as heat, cold, and dust, come into play.

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In the mechanical method these factors disappear, and the results of the test can be rapidly arrived at. For this purpose the test should deal with a minimum quantity of the lubricant, and the testing machine be constructed with this object in view.

To discover whether the first condition be fulfilled, the lubricant to be tested is applied to the outer surface of a hollow spindle and to the inner surface of a steel bearing, whose cross-section being a semicircle of a greater radius than that of the spindle immediately below it, the contact between the two metal surfaces is reduced to a minimum. Round the bearing, and attached to it, is hung a metal stirrup.

On the spindle being rotated, the perpendicular, passing through the centre of gravity of the stirrup and that of the cross-section of the spindle, is inclined at an angle from its original direction when at rest. This angle is directly proportional to the intensity of friction between the spindle and bearing with lubricant between them, and can be measured by a scale on the lower portion of the stirrup. In testing to see how far the lubricant satisfies the second condition, that is, what amount of heat it develops in a given time, a testing-machine of the following construction is used.

To produce a satisfactory test, the heat generated must be solely derived from the lubricant. To this end a spindle, whose central portion is parabolic, is employed; on the top of this the segment of a bearing is accurately fitted, and held down by a weighted lever attached to the mountings of the machine. The spindle is supported below by two mounted rollers with flanges to their ends. A certain quantity of the lubricant to be tested is now poured upon the parabolic portion of the spindle, over which it is equally distributed by a strip of leather between the rollers and the spindle being moved to and fro by an oblique ridge on one of the rollers.

The spindle, which is hollow and closed at one end by a thin corrugated steel plate hermetically sealed, is now filled with sulphuric ether fumes, whose average expansion, within the limits of temperature occurring here, is about ten times that of the atmosphere.

On the spindle being caused to revolve by means of a belt passing round its centre, the heat given off by the lubricant is imparted through the metal of the spindle to the ether fumes within; these expanding, exert a pressure on the yielding corrugated plate, and set in motion the pricker, to which it is attached by an arm. Below this pricker is an endless sheet of paper stretched round two revolving cylinders, whose axes are parallel to that of the spindle from which motion is transmitted to them by a screw and wheels. A certain number of revolutions of the spindle is thus represented by a corresponding length of paper; the proportion in this case being chosen so that two hundred and fifty revolutions of the spindle per minute move the paper 3·75 millimetres (0·15 inches).

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To avoid any hindrance to the progressive motion of the pricker mechanism is employed, by means of which the paper, at the end of every fifteenth second, presses against the pricker, releasing it again immediately.

The curve thus traced, after at first rapidly rising, soon becomes a straight line parallel to the direction in which the paper moves; after a time, if the lubricant be not renewed, its power will be exhausted, the temperature of the spindle increase, and the curve consequently again rise.

The abscissa of the curve represents the number of revolutions of the spindle, whilst the change of condition of the lubricant is represented by the ordinates; the product of the two, that is, the area between the curve and its abscissa representing the destructive action of the work in the lubricant.

Thus the power of endurance of a lubricant is inversely proportional to the area enclosed by the curve and its abscissa after any given period of time.

The Author then goes on to express the relative value of two lubricants in the contents of two parallelopipeds of equal base, whose volumes are respectively equal to the areas enclosed by the curve into the sines of the respective angles representing the values of the lubricants in the first case. It is recommended that tests be made of good lubricants, such as olive and rape-seed oils, and these used as standards with which to compare all other tests.

J. R. B.

Narrow-gauge Railway from Taviers to Embresin, Belgium.

(Bulletin mensuel de l'Association des Ingenieurs, &c., de Gand, 1882, p. 110.)

This line was constructed to open up the rich and fertile country known as the Hesbaye, previously cut off from railway communication by reason of its forming a quadrilateral between existing main lines. The railway is 9,446 metres (about 6 miles) long from its junction with the Namur and Ramilies line at Taviers to the terminus at Embresin, and an extension is proposed. The gauge is 0·71 metre (28 inches), the width at construction-level 10 feet 4 inches, and the weight of rail 30 lbs. per yard. The steepest incline is 1 in 66, and the radius of the sharpest curve 328 feet. The speed of the trains is limited to 9 miles an hour. The railway was constructed in fifteen months, ending the 1st of September, 1879, at a cost, not including equipment, of 298,500 francs (say, £12,000), or about £2,000 per mile. There is an iron bridge 420 feet long at Branchon, a viaduct at Wasseiges, and a bridge on iron piers at Taviers. The line is not fenced, and includes eighteen level-crossings, none of which are furnished with gates or have attendants. The earthwork amounted to about 60,000 cubic yards.

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The rolling stock consists of

	£
2 locomotives costing	1,440
2 brake vans	160
2 passenger carriages	360
3 jardinières	240
25 5-ton wagons	1,400
7 5-ton platform wagons	336
	£3,936

In 1881 the line carried 17,354 tons of goods, 230 parcels, and 40,294 passengers, and this traffic yielded 38,772 francs (say, £1,550), of which rather more than half was from the passengers. The cost of fuel, oil, grease, &c., averaged £18 per month. Only twelve persons are employed, *i.e.*, one inspector (*chef de ligne*), two engine-men, one stoker, one clerk, one receiver, and six workmen. The break of gauge at Taviers involves a cost of about 2*d.* per ton of goods for trans-shipment, which service is performed by a special contractor, unless the parties prefer to do it themselves by their own workmen. The trains stop to take up or set down wherever required.

The railway is the property of its concessionary Mr. Zaman, whose rights last for forty years.

F. G. D.

On the Prevention of Snow-Drifts on Railways.[1]

By G. Braet.

The Author gives in this Paper a *résumé* of the various means in use for preventing exposed lines of railway from being blocked by snow. Drifts generally form in cuttings, but occasionally also on embankments. The Author cites a case of an embankment at Geisslingen, which, although 50 feet high, causes serious trouble every year from snow. The choking up of cuttings may sometimes be prevented by making them wider, or, better still, by flattening the slopes so that the snow may drift freely away. The usual plan, however, for protecting exposed points is to erect shelter fences of masonry or timber, or to plant trees a little back from the edge of the windward side of the cutting. The latter plan has been extensively adopted, and with marked success. Occasionally, where the configuration of the ground frequently causes deep drifts to lodge on the line, or where the line crosses the path of avalanches, shelter galleries must be resorted to. All the foregoing means for preventing drifts are treated in detail, and especial prominence is given to shelter plantations.

The Author also discusses the different methods of clearing a blocked line, and describes some new forms of snow plough.

Attached to the Paper is a list of about twenty authorities dealing with the subject under consideration.

W. P.

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[1] The original pamphlet will be found in the Library, Inst. C.E.

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Bollée's Steam-Carriages. By H. DE CORDIER.

(Mémoires de la Société des Ingénieurs-civils, Paris, 1882, p. 11.)

Since the first notice of Mr. Bollée's steam-carriage was written [1] a few improvements have been made in the details. The usual expansion-link has been superseded by a circular valve, by means of which the ports are rapidly opened and closed, and high degrees of expansion can be practised, resulting, it is stated, in economy of water and fuel. A surface-condensing apparatus is now in course of trial. The engine, which had previously been set upright at the fore part of the carriage, has been, for more than two years, placed horizontally near the boiler. The speed of the feed-pump has been reduced, and, with larger pipes, the pump works very regularly. The two endless chains before employed for turning the driving-wheels are now superseded by a single chain, with differential gear.

It has been ascertained that on nearly all the macadam roads the coefficient of adhesion is equal to 0·35; but that on macadam consisting of very hard basalt this coefficient is reduced one-half, whilst on wet calcareous macadam it may be reduced five-sixths; and on the same macadam in a state of dryness it mounts up to 0·45. On pavement, the coefficient is generally much less than on macadam. Sand is an effectual remedy for slipperiness. The coefficient of traction is measured by the fact that the carriage descends an incline of 0·02, or 1 in 50, at a uniform velocity, without steam, when the road is in good condition: equivalent to 45 lbs. per ton.

There are six types of steam-carriage—three for goods trains and mixed trains, and three for passenger traffic. There are six steam-carriages of the first three types and sixteen of the last three types.

The first type of steam-carriage is provided with a tender for fuel and water. The carriage is on four wheels, and the tender on two wheels, coupled to the hind wheels of the carriage. The four coupled wheels are 64 inches in diameter and 12 inches in width; but it is intended to increase the dimensions to 95 inches and 16 inches respectively, that the road may be rolled, not crushed. There are three speeds, in the ratio of 1, 2, and 4; but in future there will be but two speeds. Preference, it is likely, will be given to boilers having horizontal flue-tubes, with 540 square feet of heating surface.

The second type of steam-carriage resembles the first type, without the tender. The third type has wheels 65 inches in diameter and 12 inches wide. The remaining three types can carry respectively forty, twenty, and ten passengers, in addition to mail-bags, luggage, and small parcels. The largest type has a tender for water. An extra carriage for passengers can be drawn by each steam-carriage.

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[1] Minutes of Proceedings C.E., vol. xliii., p. 382.

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The maximum capacity and weight of steam-cars and trains with their loads are given as follows:—First type—steam-carriage and tender, 29 tons; ten wagons, 30 tons; goods, 80 tons; together, 139 tons. Second type—steam-carriage, 19 tons; three cars, 6 tons; four wagons, 10 tons; one hundred passengers, 7 tons; luggage, &c., 6 tons; goods, 18 tons; together, 66 tons. Third type—steam-carriage, 10 tons; one car, 2 tons; two wagons, 4 tons; goods, &c., 12 tons; total, 30·4 tons. Fourth type, for express trains—steam-car, 10·5 tons; tender, 4 tons; forty passengers, 2·8 tons; goods, &c., 2 tons; together, 19·3 tons. Fifth type, express steam-car, 6·10 tons; twenty-four passengers, 1·4 ton; luggage, &c., ½ ton; together, 8 tons. Sixth type, express steam-car, 3·5 tons; ten passengers, 0·7 ton; luggage, 0·25 ton; together, 4·45 tons. For omnibus trains heavier loads can be taken.

The annual mileage run, with the receipts and expenses for average traffic, including interest, maintenance, and general charges, are summarised in the following Table:—

Type.	Miles run.	Coal Consumed per Mile Run.	Load.	Receipts.	Expenses.	Expenses per Mile Run.
No.	Miles.	lbs.		£.	£.	d.
1	9,300	88	Goods, 35 tons	2,520	1,800	46·4
2	24,800	56	Goods, 7 tons Passengers, 40 tons	4,880	2,600	25·2
3	24,800	28	Goods, 4¼ tons Passengers, 17 tons	2,440	1,680	16·3
4	46,500	28	„ 20 „	5,760	2,800	14·5
5	46,500	10½	„ 10 „	2,880	1,920	9·9
6	41,000	7	„ 10 „	1,900	1,440	8·4

Considerable experience has been gained of the working of the steam-cars in France—between the Trocadero and Sèvres—in 1878; and, in May 1879, on the road between Mans and Alençon, where speeds of from 20 to 25 miles per hour were attained. A public service was inaugurated in August 1881 between two bathing-places—Heiligendamm and Doberan, in the Grand Duchy of Mecklenburg. In the same month another service was instituted between Richtenberg and Stralsund (Pomerania) on a road 13 miles long, by means of steam-cars taking mixed trains at a speed of about 10 miles per hour. The road has been consolidated under the traffic as if it had been steam-rolled. Paved inclines are coated with sand after each heavy fall of rain. The system of steam-traction is at work in most of the principal countries of Europe. A steam-car of No. 5 type, weighing 5 tons, travelled a distance of 62 miles—between Tour and Mans—in four hours, five minutes, including stoppages, with a consumption of 5·30 lbs. of coal per mile, and 27 lbs. of water per mile.

D. K. C.

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On the Speed and Power of Railway Trains.

By Dr. H. SCHOEFFLER.

(Organ für die Fortschritte des Eisenbahnwesens, vol. xix., 1882, p. 60.)

This article gives the methods used on the Brunswick Railways for fixing the speed and size of trains, according to the gradients and curves on the line. The rules are approximate only, but sufficient for practice. The maximum speed in any given train may be determined from two points of view; (1) that of the power of the engine, (2) that of safety in running. For speeds below the lower of these two limits no rule can be given which does not include the fuel expended, and this embraces general considerations of economy, &c.

(1) *Speed at constant expenditure of Fuel.*—Let a be the train resistance, b the weight of the engine and tender, f the number of axles in the train (supposing an average load on each, say 5,000 kilogrammes), 1 in n the gradient, r the radius of the curve. The resistance of the train may be taken at $\frac{1}{300}$ of its weight; that of the engine as $\frac{1}{150}$. But to this must be added the resistances due to the air, &c., which are such that if b be expressed in the corresponding number of train axles, it will have a value varying from $4 \cdot 5\, b$ to $11\, b$. The resistance due to the curves may be expressed by adding to the gradient $\frac{3}{4r}$. From these figures the following formula is obtained, as representing the work done per hour by an engine at a speed of v kilometres per hour:—

$$\left[a + f + 300 \left(\frac{1}{n} + \frac{3}{4r} \right) (b + f) \right] v.$$

From this expression the velocity v of a given load can be determined. Also the velocity v, or the time t, for a given length of track can be determined in terms of v_1 and t_1, the values for the same train on a straight horizontal road; or in terms of v_0 t_0, the values for the engine alone upon a straight horizontal road.

These formulæ show that the time per hour increases by a percentage of the time t_0, which percentage increases as the gradients are higher and the curves sharper. If it be determined to keep the time constant, a virtual length may be substituted for the real length of the line increased in the same proportion. This, throughout assumes that the consumption of fuel is constant, which is by no means a good assumption for practical working.

(2) *Maximum speed with a given power of Engine.*—If the consumption of fuel is varied, the speed can evidently be increased up to the maximum power of the engine, or up to the limit of safety. The lower of these limits must be taken as the highest

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admissible speed. Now, for ordinary speeds the resistance of a train of x axles may be taken as proportional to

$$\left[1 + 0{\cdot}1\, v + 1{,}000\left(\frac{1}{n} + \frac{3}{4r}\right)\right] x,$$

where v is the velocity, $\frac{1}{n}$ the gradient, and r the radius of the curve. The resistance of the engine, taking its weight as equal to that on b axles, is given by

$$d + \left[1 + 0{\cdot}1\, v + 1{,}000\left(\frac{1}{n} + \frac{3}{4r}\right)\right] b,$$

where d is a number found from the resistance of the engine at the minimum speed. By adding these two formulæ together, an expression is obtained for the total resistance which the engine has to overcome at a given speed. The power of the engine being known, the maximum speed can then be calculated; or if the limit of speed is fixed, the number of axles it can draw at that limit can be calculated. Examples of the calculation are given.

Taking v_1 as the velocity on a straight horizontal road, the following formula is obtained—

$$v = v_1 - 10{,}000\left(\frac{1}{n} + \frac{3}{4r}\right)$$

which shows how the speed is to be reduced to correspond with any given gradients and curves. If in the above formula $v = 0$, the greatest number of axles are found which a train can move upon a given gradient.

(3) *Maximum Speed with reference to the conditions of the Road.*—The question of safety will often fix the maximum speed. In Germany, on gradients below 1 in 200, and curves of more than 1,000 metres radius, the maximum speed allowed is 90 kilometres per hour (55 miles) for express trains, 75 for ordinary trains (45 miles), and 45 for goods trains (27 miles); and this must be reduced on steeper gradients or sharper curves.

The distance x, in which a train will be brought to rest under the action of brakes, is given by the expression

$$\frac{v^2}{2g\left(\frac{1}{m} - \frac{1}{n}\right)},$$

where v is the speed, $\frac{1}{n}$ the falling gradient, and $\frac{1}{m}$ the retarding resistance, taken as a fraction of the weight of the train. Putting

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v equal to maximum speed, this gives the value for n on which this speed is allowable. The speed on any other gradient $\frac{1}{n}$ is given by

$$v\left(1 + \frac{m}{2n} - \frac{m}{2n^1}\right).$$

The quantity m depends, of course, upon the brake arrangements. In Germany, passenger trains on gradients of 1 in 200 must have one-fifth of the wheels braked. If it be assumed that half the weight of the engine and tender is available for braking, and that the coefficient of friction is $\frac{1}{10}$, then $m = 20$ for express trains, $m = 30$ for passenger trains, and $m = 40$ for goods trains. On these data a Table is constructed, giving the maximum speed for the three classes on various gradients. The distance, in which the train will be brought to rest are as follows:—

Express trains, 600 to 700 metres (say 700 yards).
Ordinary trains, 700 to 800 metres (say 800 yards).
Goods trains, 300 to 400 metres (say 400 yards).

With regard to curves, it may be assumed that the centrifugal force is to be always the same; and a Table constructed on this basis is given. It may be objected that the raising of the outer rail should be considered; but the German State regulations take no account of this, and it appears, in fact, that the relation between the speed and the radius of the curve is not altered thereby. The practical results are as follow: on gradients of 1 in 200 to 1 in 80, and curves of 1,100 to 900 yards radius, the speed must be reduced by one-eighth; on gradients of 1 in 80 to 1 in 40, and curves of 900 to 650 yards radius, by one-quarter; on curves of 650 to 450 yards radius, by three-eighths; on curves of 450 to 275 yards radius by one-half.

(4) *Maximum Speed with reference to the construction of the Engine.*—This point cannot be treated theoretically. In fixing the highest speed at which a given engine will run easily, account must be taken of all points in construction which tend to produce rolling, jolting, and other irregularities. Such points are: (*a*) the number of coupled wheels, whether 0, 4, or 6; (*b*) the overhang beyond the leading axle, which varies between 1·4 and 2·16 metres; (*c*) the overhang beyond the trailing axle, which varies between nothing and 2·46 metres; (*d*) the stroke, which varies between 0·53 and 0·66 metres; (*e*) the height of the centre of gravity of the empty boiler above the rails, which varies between 1·6 and 1·9 metre; (*f*) the distance of the cylinder centre-line from the engine centre-line, which varies between 0·37 and 1·01 metre; (*g*) the distance of the middle of the cylinder in front of the centre of gravity.

In all the above the evil increases as the dimensions increase. In those which follow, it increases as the dimensions diminish.

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These are: (h) the diameter of the driving wheels, which varies between 1·1 and 1·83 metre; (i) the distance of the centre-line of the driving-axle brasses from the engine centre-line, which varies between 0·57 and 0·96 metre; (k) the wheel-base, which varies between 2·0 and 4·57 metres, and which belongs to this class, except on very sharp curves, where it would belong to the former class.

The Author discusses these various elements, and arrives at the following formula (for dimensions in metres):—

$$v = h(63 - 2{\cdot}5\,a - 2{\cdot}2\,c - 16{\cdot}8\,f).$$

The influence of the quantities (b), (d), (e), (g), (i) and (h) is here neglected.

From this formula the Author has constructed a Table, part of which is subjoined.

Class of Engine.	Diameter of Driving Wheel. h	Number of Axles Coupled. a	Overhang behind. c	Distance of Cylinder-axis from Loco-axis. f	Maximum Speed. v	
	Metres.		Metres.	Metre.	Kilom.	Miles.
Prussian normal passenger engine .	1·730	2	1·585	0·940 (outside)	71·3	44·3
Prussian normal goods engine . .	1·330	3	2·645	1·015 „	46·7	29·0
Lilleshall Co. express engine . .	2·134	..	0·700	0·380 (inside)	117·5	72·7
Great Northern railway express engine . .	2·465	..	0·500	1·000 (outside)	111·2	69·0
London, Chatham, and Dover Railway express engine . .	1·980	2	1·219	0·356 (inside)	102·6	63·4

The general result is that no single formula can be given for the speed of trains, which must be regulated by the lowest of the three limits assigned by the power of the engines, by their construction, and by the conditions of the road. Certain general rules may be laid down. The maximum speed consistent with the curves and gradients should first be determined. If there is no limit in the choice of locomotives, this maximum speed can always be realised; but if there is no stringent necessity for it, it is better to reduce the speed, from considerations of economy in fuel, and in wear and tear. If, however, the class of engines to be used is fixed, their maximum speed, as determined both by their power and their construction, must be found; and the lower

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of these forms the limit of speed for that particular set of engines. This may of course be diminished as before from economical considerations.

W. R. B.

On Intercommunication-Signals for Railway Trains.

By F. MAGDALINSKI.

(Organ für die Fortschritte des Eisenbahnwesens, vol. xix., 1882, p. 70.)

The above name may be given to all apparatus for signalling between the different persons on a train, whether between driver and guard, driver and passengers, or passengers and guard. The first is by far the most important, especially on German railways, where there are often two or three brakesmen in addition to the guard. The driver has to signal for the putting on and taking off the brakes, and the guard has to signal danger and stop. The former signals are generally given by the steam whistle, and, on German railways, the latter also; it being obligatory that there should be a cord passing from the engine-whistle to the guard's van.

Communication with passengers is far more difficult, and has not been carried out with complete success. The first idea of the kind was the crude one of placing in each compartment a red flag, to be shown through the window. The defects of this are apparent. In 1865 the French Ministry of Commerce took up the question, and insisted that the railways should adopt some method for this purpose. That recommended and adopted by most lines was Prudhomme's electric system, which gives the means of communication both to passengers, drivers, and guard, and also warns both driver and guard if the train breaks in two.

Experiments made in Prussia in 1869 led to no satisfactory result; but in 1873 the Government decreed that express trains were to be fitted with some such system within six months. In consequence a conference of railway officials was held in Brunswick in January 1874. It was decided that there was no time for exhaustive experiments, and, by a majority of fifteen to four, that mechanical were to be preferred to electrical apparatus. Experiments were subsequently made, both with electrical appliances and also with mechanical, especially the English cord. The result was favourable to the latter, and in 1878 the Oder-Ufer Railway was the only one in Germany which employed electric communicators. The mechanical appliances used may be divided into the following heads:—1. The ordinary guard's cord, placed so as to be accessible from the window; 2. The same cord with an attachment coming within the carriage; 3. The English cord connected with a bell in the driver's cab; 4. A line inside the carriage connected with the steam-whistle; 5. A wire outside the carriage, which by a trigger arrangement operates on an alarm signal in the brake van; 6. A

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bell on the carriage, rung by a cord from inside; 7. Explosives on the roof of the carriage worked from the inside.

The object of all such signals is to destroy the complete isolation of each compartment in a train, especially with a view to cases of outrage. But a signal requiring to be made by the passenger is of little use, inasmuch as the person committing the outrage can easily prevent its being made. The most effectual method is some system of communication between compartments, which yet shall not destroy the privacy sought by first- and second-class passengers. In the third class no such precautions are needed, as there no outrages occur; first, because there is less temptation, and secondly, because the compartments are generally open to each other at the top. Now the complete separation of the three classes is no doubt needed; but there seems no reason why, between compartments of the same class, there should not be some communication, as is actually the case in the third class. The openings should be at the top of the partitions, and should have sliding doors, so that they might be closed at will. As far as outrages are concerned, therefore, intercommunication signals are of little importance. It is otherwise with the accidents which may happen during a journey to the rolling-stock, such as the heating of a box. It is then desirable to stop the train as speedily as possible; and in their own interests companies should give passengers every facility for doing so directly, and not merely for signalling to the driver. At present the utmost achieved is that the driver shall receive a signal to which he is bound to attend. In many cases he is merely bound to ascertain what the cause of the signal is; but this is a dangerous measure, as safety may often depend upon the immediate stoppage of the train. Experience shows that there is no fear of the public using the signal unnecessarily. Thus on the Berlin-Hamburg railway there have been only twenty-one cases of use in seven years; and while none of these were merely frivolous, one case probably prevented a serious accident.

With regard to the two systems of signals, the mechanical and the electric, the latter is far the most costly in installation and maintenance, and, from the delicacy of the connection, much more likely to fail when required. An acoustic signal on the engine, worked by some mechanical means along the train, is the best type for such an apparatus. A bell on the carriage (No. 6 above) is insufficient, and the explosive arrangement (No 7) too uncertain. It seems therefore that the two methods are available, either of making the ordinary guard's cord accessible to the public, or of having a separate alarm cord within or without the carriage. Since the signal in all cases is to be answered by stopping the train, the single cord seems to give all that is required. It is desirable that it should be a continuous cord, and not one which has to be coupled up between each carriage, as in the latter case the interposition of a strange carriage in a train may make a break in the continuity. W. R. B.

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Stoves for Heating the Refreshment-Cars of the Berlin-Anhalt and Thuringian Railway. By — Stösger.

(Organ für die Fortschritte des Eisenbahnwesens, vol. xix., 1882, p. 120.)

Each of the refreshment cars contains two stoves, which are replaced by seats as soon as the summer comes on. The stove consists of an inner wrought-iron cylinder, to the top of which is screwed a cover. A second cylinder, also of wrought iron, surrounds the inner one, and is connected to it, at the top, by four screws. The lower end of the outer cylinder, which projects beyond the inner one, contains a grate 4 inches from its bottom. In the front of the outer cylinder are two openings provided with doors, one above, the other below, the grate. A flue, over the top of which is fastened a shade, is situated at the top, at the back of the outer cylinder. The lower portion of the stove is surrounded by a guard, or fender, of sheet metal screwed down to the floor of the car. Preparatory to heating the stove, the cover, at the top of the inner cylinder, is removed. Coal or coke, with the necessary wood and shavings, is dropped from above on to the grate, the cover replaced and screwed down, and the material lighted from the opening above the grate. The smoke and gases escape through the lower end of the inner cylinder, up along the outer one, and out at the flue.

As soon as the requisite degree of heat has been attained, the doors of the openings, above and below the grate, are closed, and the supply of air to the fire regulated by a sliding panel in the lower door.

J. R. P.

On the Breakages of Axles and Tires.

By M. Worms de Romilly.

(Annales des Mines, 1882, p. 501.)

This Paper contains an analysis of the failures of axles and tires on the Northern Railway of France, during a period of five years, from 1876 to 1880. From the results of two hundred and sixty-three iron axles of tenders, carriages, and wagons, it appears that, of sixty-one tender axles, all of them gave way at a journal; of which fifteen were broken, four were cracked, and forty-two were bent or twisted (*forcés*). Of two hundred and two axles of carriages and wagons, six were broken in the body, one hundred and fourteen were broken at a journal, sixteen were cracked in the body, and one was cracked in a journal. The result is, that whilst the tender axles failed mostly by bending or twisting at a journal, due to the action of brakes, no doubt, the axles of carriages and

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wagons failed entirely by rupture. The mileage run by axles averaged as follows:—

—	Miles Run, Average.	Maximum.	Minimum.
Iron axles of tenders	220,000	463,000	50,500
„ „ „ carriages and wagons . .	194,000	326,000	20,400

During the same period, two hundred and eighty-one axles of locomotives gave way, classified as in the following Table:—

Axles.	Number of Axles.	1	2	3	4	5	6	7	8	9	10
Crank-axles—steel	30	13	..	1	..	13	..	..	2	1	..
„ „ iron	126	16	2	..	4	97	2	..	1	..	4
Straight driving-axles, coupled—steel	3	..	..	..	..	..	..	..	..	..	3
Straight driving-axles, coupled—iron	18	..	1	2	..	..	..	1	..	..	14
Straight driving-axles, single—iron	29	..	4	1	..	..	2	16	..	..	6
Straight axles, coupled—steel	8	..	1	3	..	..	..	..	..	1	3
„ „ „ iron	38	..	..	3	..	..	1	1	..	1	32
Carrying axles—iron . . .	29	..	..	..	..	..	..	1	..	1	27
Straight axles—steel—total .	11	..	1	3	..	..	..	..	..	1	6
„ „ iron—total .	114	..	5	6	..	..	3	19	..	2	79
Crank axles—steel or iron—total	156	29	2	1	4	110	2	..	3	1	4
Straight axles—steel or iron—total	125	..	6	9	..	..	3	19	..	3	85
Total of all kinds	281	29	8	10	4	110	5	19	3	4	89

Columns 1, 2, 3, 4, comprised cases of rupture, respectively at the crank-pin, in the body, in a journal, and in a crank. Columns 5, 6, 7, 8, comprise cases of cracking, without rupture, at the same places correspondingly. Columns 9 and 10 comprise cases of twisting or bending in the body, or in a journal.

The crank-axles failed mostly by the rupture of the crank-pins; but, whilst the cracks are equal in number to the ruptures on the steel axles, they predominate in the iron axles; showing that iron axles are safer than steel axles, in so far as cracks give longer premonitory notice of failure in the iron axle than in the steel axle. The Author accords the preference to axles of iron.

Of the straight carrying-axles, 93 per cent. of the failures take place at the journals, where the axle is subject to stress by the axle-guards. Single driving-axles fail mostly by cracks in the journal. Coupled axles generally fail by twisting or by bending.

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The mileages run by the locomotive axles above noticed were as follows:—

—		Number.	Miles Run. Average.	Maximum.	Minimum.
Crank axles	Steel	30	99,400	325,000	5,360
	Iron	126	151,000	476,000	41,600
Straight axles, single	driving—iron	6	133,000	293,000	9,800
	carrying „	21	159,400	461,000	36,200
Straight axles, coupled	driving—iron	18	159,000	364,000	35,000
	coupled „	38	180,000	355,000	35,000
„	carrying „	6	161,000	268,000	1,630
Straight axles, coupled	driving—steel	3	18,700	29,000	13,600
	coupled „	8	86,000	452,000	8,560

In the course of an analysis in detail of the results of wear and tear of tires, it appears that the average miles run by engine-tires of Bessemer steel are 49,000, against 27,500 miles run by cast-steel: they fail by rupture of tender tires—the life is 34,400 miles, against 23,800 miles. For carriages and wagons the mileage run by Bessemer tires is 44,400, against 63,100 miles by cast-steel tires.

From the results of wear of tires which are regularly worn out, cast-steel appears to be better than Bessemer steel for single driving-wheels and carrying-wheels of engines; but for tenders, Bessemer tires are the better.

The Paper contains many Tables of comparative data.

D. K. C.

Breakage of Pit-Ropes. By L. Aguillon.

(Rapport sur la Rupture des Câbles de Mines, Paris, 1881, pp. 1–122.)

In consequence of several fatal breakages of wire ropes in winding-shafts, a commission was appointed by the French government in 1878, with the Author as secretary, to enquire generally into the safety of wire ropes used for conveyance of men; the investigation was extended to ropes of all kinds and for all mining purposes. Having occasion in 1880 to visit Belgium, England, and Germany, on behalf of the French fire-damp commission, the Author took advantage of the opportunity to collect information in these countries also on the question of ropes. His report gives the results of the enquiry, firstly in France, and secondly in the three other countries; and sums up the practical conclusions to which the facts so ascertained seem to lead. Safety is throughout made the primary condition, and economy ranks second. Some of the information here collected has already been given at greater length

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in a Paper on wire ropes,[1] by Mr. Garcenot; in another on steel wire for ropes,[2] by Mr. Bonnaud; and in a third on pit-ropes,[3] by Mr. Wenderoth; the two former deal with French experience, the third with German.

In regard to the material for pit-ropes—whether hemp, or iron or steel wire,—and their shape, whether round or flat—the advantage attributed to hemp ropes, of giving warning before they break, is shared equally by wire ropes when properly looked after, and the latter can be employed with as much safety as hemp ropes, when proper care is bestowed upon everything affecting their working. In wet pits, particularly where the water is at all corrosive, or where it is wound up in buckets instead of being pumped, aloes ropes are preferable. But in upcast-shafts, however slightly warm be the air-current, wire ropes should be used, in spite of the disadvantage of their hemp core. In the absence of any such special reasons, the choice of material is more a question of economy and convenience than of safety. Where it is determined that the rope shall be flat instead of round, the power of the winding engine in deep pits can be better balanced with a hemp rope; because a flat wire-rope is too thin to alter the leverage quickly enough in coiling or uncoiling on the rope roll, and would involve some kind of counterbalance, which would be a matter of difficulty. This is the practical reason why several deep pits in France have recently changed from flat wire-ropes to flat aloes-ropes. With wire too there is much more difficulty in making a good flat rope than a good round one; and round ropes winding on conical or spiral drums afford a convenient means of balancing the engine-power. As to the choice between steel and iron for wire ropes, German and English practice goes to show that steel ropes, well made and of a suitable quality of steel, are capable of working better in all respects, and appear even to be safer. The exclusive use of steel-wire ropes in Germany and England, and of hemp or aloes ropes in Belgium, for all depths of pit, is attributed to the degree of excellence which has been arrived at in the two former steel-producing countries in the manufacture of steel wire, of sufficiently homogeneous quality and otherwise suitable for ropes; whereas in Belgium the manufacture of aloes or hemp ropes has always been a special industry of Flanders, where it has attained a rare degree of perfection. The whole of the winding gear should always be carefully adapted to the particular material of which the ropes are made. In France the mistake has generally been committed of ordering a rope without giving the maker any idea of the conditions under which it is to work, the very make being often specified for him in detail. Elsewhere the more sensible practice is to consult with the maker throughout, furnishing him

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[1] Minutes of Proceedings Inst. C.E., vol. lxvii., p. 506.
[2] *Ibid.*, vol. lxvii., p. 509.
[3] *Ibid.*, vol. lxviii., p. 410.

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with complete information as to the whole of the requirements to be fulfilled.

In addition to being tested, all ropes should be guaranteed by the makers. In Belgium the guarantee for aloes ropes is generally that they shall last from 1½ to 2 or 2½ years, or else for a given output; and 1-12th or 1-24th of their value is deducted for every month short of their stipulated duration. At the Royal Collieries at Saarbrücken, the ropes, of English crucible cast-steel wire, are guaranteed for six weeks, during which the maker is held liable to replace them if found defective.

Testing should apply, for hemp and aloes ropes, both to the raw material itself and to the spun yarn, as well as to sample lengths of the finished ropes. The twist of the rope, and the stitching of a flat rope, should be very uniform; and the rope should not contain more than 20 per cent. of tar.

Iron wire for ropes should be strong, hard, pliable, and not galvanised; and should be selected from such standard makes as those in France of Berry and Franche-Comté.[1] Steel wire should be made from crucible cast-steel, of very homogeneous and comparatively hard quality, and suitably annealed; it should have a tensile strength of 70 to 76 tons per square inch, and should stretch 3 to 5 per cent., and be pliable. It should be tested for tensile strength, stretching, bending, and torsion;[2] and all the wires in the same rope should be as closely alike as possible. Sample lengths of the rope itself should also be tested. The lay of the wires and strands should be regular; in flat ropes the stitching should be regular, and should be done with annealed wire. Torsion is considered an excellent test for homogeneous quality in wire: steel wires of 0·059 inch and 0·118 inch diameter should stand twisting through 40 and 20 revolutions respectively in an unloaded length of 6 inches; and the surface markings produced by the twisting should follow regular lines.

The size of the wires, and the length of their lay or pitch in the rope, should vary in accordance with the diameter of the drums and pulleys round which the rope will have to work; and particularly with the distance between the drum and the pit-head pulley, and with the angle which the inclined span winding on the drum makes with the vertical portion hanging down the pit. These are essential points for determining the stiffness requisite to prevent the rope from flapping as it runs.

Experience proves that the very material itself of every rope does certainly undergo deterioration in working, thereby diminishing the rope's strength till it becomes no longer safe. This deterioration of material is something more than mere wear by friction or rusting: in aloes ropes, the fibres lose their strength; and in wire ropes, even where testing fails to show any loss of tensile strength per square inch of section, there is a clear diminu-

[1] Minutes of Proceedings Inst. C.E., vol. lxvii., pp. 506–512.
[2] *Ibid.*

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tion of pliability and elasticity; the wires become harsh and brittle, whereby the rope is weakened. Though the deterioration is generally accompanied by unmistakeable external indications, it is yet desirable to trace its progress by actual tests of the individual wires, or of the ends of the rope itself. However well a rope may seem to be lasting, it should always be suspected as soon as its duration approaches the average that corresponds with the conditions under which it is working; it should at any rate cease to be used where its breakage could endanger life.

Large diameters for drums and pulleys are of more importance for wire ropes than for hemp, and for steel than for iron. The smallest diameter should be at least 1,300 or 1,400 times that of the iron wire in a rope, and 2,000 times that of the steel wire. Its relation to the size of the rope itself matters less, because the disadvantage of too small a diameter can be obviated by selecting a suitable size of wire and by a suitable make of rope. It is well however for the smallest diameter of pulley or drum to be not less than 80 or 100 times the diameter or thickness of a wire rope, and 50 times for a hemp rope.

The rope should wind smooth on the drums or pulleys, without rubbing sideways against them, and so as to run free from jolts and flapping. For wire ropes it is desirable to line the grooves of the pulleys with wood. The larger the diameter of the headgear pulley, the less does it matter how small be the angle which the inclined span winding on the drum makes with the rope hanging down the pit; but with smaller diameters of pulley the angle should be increased, in order thereby to diminish the bending of the rope in passing over the pulley. Opinions differ as to the minimum angle to be allowed; some assign 40° as the limit, while according to others it should never be less than 60°. In plan, the obliquity of a round rope between the overhead pulley and the drum should always be kept within the smallest possible limits.

In doubling back the rope end for attaching it to the cage, the loop should be kept as large as possible, by inserting within it an iron eye or a wood disk; this is particularly advisable with iron wire-ropes, and still more so with steel. The attachment should also be made with springs, for easing the jerk at starting.

Iron or steel wire-ropes of large size should not work at more than one-tenth of their breaking strength; small round ropes may be worked up to one-sixth. Well-made aloes-ropes may be loaded to one-seventh or one-eighth.

Careful maintenance is indispensable to the preservation of all ropes, especially of wire ropes. Hemp ropes want tallowing regularly, and aloes ropes want keeping always damped. Wire-ropes, steel particularly, should be greased regularly, and often enough to prevent their ever beginning to rust. The grease should be soft enough to work into the strands, right through to the hemp cores, but stiff enough to stick on the outside of the rope. A mixture of oil and grease, well stirred and laid on hot with a brush, answers very well; both oil and grease should be neutral.

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Tar by itself does not do very well; but 75 per cent. vegetable tar with 25 neat's-foot oil, or 80 per cent. tar with 10 olive oil and 10 tallow, has been found a good mixture.

From every rope, the end attached to the cage, being the part that wears worst, should be cut off regularly every two or three months, shortening the rope two or three yards each time, so as to bring a fresh portion to take the extra work at the pit-head pulley on starting. In order to note the progress of deterioration, the end so cut off should itself be tested entire, if possible; or at any rate the component wires individually. These two precautions are strongly insisted upon as of vital importance for wire-ropes; they are too much neglected in France.

Splicing should not be attempted in any other way than by untwisting the ends to be spliced, and then so twisting them together as not to alter the size of the rope. It requires to be done with the utmost care by specially skilled workmen; and a spliced rope, particularly of wire, should never be trusted. Splicing by lapped joints or by hinged plates should never be resorted to, as extra strain is thrown on a splice so made in passing round pulley or drum.

Besides the watching they get from the enginemen and landers, which may be stimulated by a reward for every defect pointed out, all ropes should be examined daily by a competent person, the empty cage being raised and lowered slowly enough to give him time for examining them well. With wire ropes this examination should at least once a week be so thorough as to ensure counting the number of worn or broken wires in the portion that seems most worn. Wherever possible, it is well also to arrange for an independent examination monthly or weekly by the foreman of the ropemaker, as is done in Belgium, and to record all the several particulars.

Where safety of life or limb is involved, no rope should be used that is not perfectly sound; for all such work therefore spliced ropes should be prohibited, as well as any that have already lasted two-thirds of their average duration. A new rope should be tested with several days' winding, before men's lives are trusted to it. With living freight, the load on the ropes should be much lighter, and their speed only half or two-thirds of what is otherwise usual. Whenever either rope in a shaft is winding men, its fellow rope should not be allowed to be doing any other work. All slack in the rope should be taken up before any one is allowed to enter the cage; and the winding engine should be so handled as to ensure the ropes running without jerk, jolt, or flapping.

It is not considered necessary that any of the foregoing recommendations should be enforced by law, but only that attention should be drawn to them. The desirability is urged of arranging for a systematic record of the statistics of mine ropes, such as is carried out in Germany.[1] Tabular illustrations are given of the

[1] Minutes of Proceedings Inst. C.E., vol. lxviii., pp. 410-411.

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information so obtained there; and examples are appended of the enquiries made for eliciting the particulars desired, as well as of the codes of regulations adopted for the safe working of the ropes.

The excellent working of steel wire-ropes in English pits, as regards both safety and durability, is ascribed to their being so carefully manufactured with wires of good quality, selected for the purpose; to their being so thoroughly examined while working, and being kept always so well greased; to the use of drums and pulleys of such large diameter; to the general practice of not winding from more than one depth in any one shaft, and to the consequent possibility of keeping the ropes always taut, as is done by the skill acquired in handling the engines. It is only in the attachment of the ropes to the cages that English practice seems not up to the mark; the attachment is generally made by a wrought-iron strap clamped on the rope, instead of by the preferable plan of doubling the rope end back. Iron-wire guide-ropes are very commonly used in England, even for depths of nearly 800 yards and speeds of over 20 miles an hour.

A. B.

On the Dubois and François Method of Driving Galleries.

By V. WATTEYNE.

(Annuaire de l'Association de l'École de Liége, 4th series, vol. i., p. 17.)

At the Alliance pit of the Bois de Bossu colliery, near Mons, a level, intended to cut a lower group of seams, was in progress, by the aid of boring-machines and dynamite, when a sudden influx of gas prevented the further use of blasting. A method which had previously been employed, that of boring a series of holes almost touching each other and breaking down the intermediate portions with steel wedges, was then tried; but, from the extremely hard character of the rock, it was not successful, the weekly advance of the gallery being quite insignificant. It was therefore decided to have recourse to the "Bosseyeuse" of Dubois and François. This is a boring machine of extra large size, so mounted as to be capable of vertical and lateral motion about the point of attachment, in addition to the ordinary longitudinal movement in the direction of the work. Three classes of tools were used, namely: (Z) 1. borers of the ordinary kind, those with cross-cutting edges deeply notched in the angles being preferred for hard, and Z-faced ones for easier ground; 2. a toothed borer or beating saw, with a series of parallel teeth on the cutting face which removes the ribs separating the holes; and, 3. a steel mace for driving the wedges used in breaking down the under-cut rock. The first operation consists in boring in a horizontal line, about 1 metre from the ground, a series of holes 80 to 100 millimetres in diameter and about 900 millimetres deep, which will be separated by intervals of 120 to 150 millimetres. The

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borer is then replaced by the saw-edged tool, which has a rectangular face 140 millimetres by 50 millimetres, with five V-shaped cutting edges, placed slightly askew to the shorter sides. This removes the ribs between the holes, giving as a result a horizontal slit, 80 to 100 millimetres wide and 900 millimetres deep, along the entire face. For a short time another method of working was tried in which holes were bored only at the ends of the line, the intermediate ground being cut out by a saw-faced tool with a circular instead of a rectangular front, which was made to move slowly along the face; the working going on without interruption, except when it became necessary to replace the blunted tool, which usually happened about every third passage over the ground. When the slit had attained a certain depth, the work was continued with an ordinary eight-edged crown borer. The use of the second method was, however, soon discontinued, partly from the excessive wear in the tools, but more particularly on account of the intense shower of sparks given off, which were considered likely to be dangerous in an atmosphere of gas. The time required to cut the slit was much the same with either method, and varied from eight to ten hours according to the hardness of the rock. The last operation, that of wedging down, is performed by driving a series of holes at any convenient distance from the slit according to the nature of the ground, into each of which a pair of half-round plugs are placed loosely with a tapered steel wedge between them. This is then driven home by the macehead worked by the machine, and the rock is cracked and split off. The wedges are 950 millimetres long, and the half-round plugs 900 millimetres. Care must be taken in placing the latter to leave a free space of 100 millimetres at the bottom of the hole. The section of the level was square, 2,200 millimetres in the side; the average rate of driving was 1,610 millimetres per week, or 18 metres in two and a half months. The average cost was 300 francs per metre, not including depreciation of plant; the separate items being—

	Francs.
Labour (underground)	120
Wear of tools	70
Cost of compressed air	110
	300

In conclusion the Author points out that the use of the method may not be unaccompanied with danger, although no accident actually took place during nearly three months' work. The character of the sparks given off varies with the hardness of the ground; when it is very hard, they are quite as brilliant as those of the old steel mill used in lighting collieries before the invention of the safety lamp, and which is known to have caused at least one explosion.

H. B.

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On the Determination of the Pressure and Effective Section of Ventilating Currents. By R. HAUSSE.

(Jahrbuch für das Berg und Hüttenwesen in Sachsen, 1882, p. 46.)

In the comparison of the relative effect of different methods of ventilating collieries, proportional numbers of two kinds have been proposed. The first of these is the "Orifice équivalent" of Mr. Murgue, of the Bessèges Company, which gives the section of an orifice (a) on a thin plate, corresponding to the measured volume of air V at the observed depression of the water-gauge h, the simplest expression being

$$a = 0{\cdot}012 \frac{V}{\sqrt{h}}.$$

The second, the "Mechanical temperament," of the mine of Mr. Guibal, is the quotient of the square of the measured volume; divided by the observed depression. In either case, therefore, the question arises, how is the pressure corresponding to a particular volume to be correctly determined, as the readings of a gauge attached to the casing of a centrifugal ventilator, vary with its position, and do not therefore necessarily correspond to the true depression in the main return air-current? In order to establish the relation between these quantities numerous experiments were made by the Author on the Guibal fan at the Royal Colliery at Zaukerode, in Saxony. The casing of the fan, which is 7 metres in diameter, was bored through at twelve equidistant places 250 millimetres apart, the outermost being 3,500 millimetres, and the innermost 500 millimetres radially distant from the axis of rotation; and in each hole a tube of 18 millimetres bore and 500 millimetres long, was fixed, to which the water-gauge could be attached by a rubber connection. The depression of the gauge was observed at the different points under varying conditions of speed—fifteen, thirty, forty-five, sixty, and seventy-five revolutions per minute; and in all cases the readings diminished from the centre towards the circumference, being for the same speed from 2·4 to 3·6, or an average of 2·8 times greater in the former than in the latter point; while the increased effect due to augmentation of speed was nearly the same for all positions of the gauge.

The corresponding observations on the return air-current were made by boring a series of holes in the intake drift of the fan, and inserting pipes, which could be lowered to definite points in the current, the observations being made at thirteen different points in the cross-section, which are grouped in vertical and horizontal zones in the tabulated results. The gauge was placed at the top of the tube, and at the lower end of the latter a horizontal branch with a funnel mouth was attached, that could be either turned in the direction of or facing the current, the difference of pressure due to the different positions being, however, very small, and not ex-

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ceeding 1 millimetre when the speed of the fan was under sixty revolutions per minute. By comparing the two series of observations it was found that the pressure in the current corresponded to that at a different point in the fan-casing for each particular speed. Thus,

At 15 revolutions	the reading was	3·2 mm.,	corresponding to a radius of	2,900 mm.
30	,,	11·7	,, ,,	2,200 ,,
45	,,	25·9	,, ,,	1,850 ,,
60	,,	49·5	,, ,,	1,315 ,,
75	,,	74·6	,, ,,	900 ,,

Expressing the latter numbers by their difference in distance from the circumference, 3,500 millimetres, and dividing by the number of revolutions, an average constant of 38·2 millimetres is obtained, which gives the distance by which the position of the gauge must be varied for each alteration in the number of revolutions, in order to obtain the effective vacuum in the current for observations on the fan. This position s is given in terms of the radius r for n revolutions. Thus,

$$s = 0{\cdot}011\, r\, n.$$

In practice, the position of the gauge on the fan-casing will be a fixed one, and the observations must be corrected by a coefficient ϕ, obtained by dividing the results of a preliminary series of observations into the corresponding values obtained simultaneously in the drift at different speeds. In the particular case described, the gauge is 1,250 millimetres radial distance from the centre of the axle, and the corresponding values of ϕ are:—

$$\text{For 15 revolutions} \frac{3{\cdot}2}{4{\cdot}5} = 0{\cdot}71$$

$$45 \quad \text{,,} \quad \frac{25{\cdot}9}{27{\cdot}0} = 0{\cdot}96$$

$$75 \quad \text{,,} \quad \frac{74{\cdot}6}{71{\cdot}0} = 1{\cdot}05$$

The depression in the return air-current, when at a considerable depth below the surface, may also be calculated from simultaneous barometer and temperature observations above and below ground. By inverting the ordinary Gay-Lussac hypsometric formula, $s = 18363\,(1 + 0{\cdot}00367\,t) \log \frac{p}{p_1}$, the atmospheric pressure p corresponding to a known depth s and temperature t, from the pressure p_1 and temperature t at the surface. Thus,

$$p = \text{num}\left(\log p_1 + \frac{s}{18363\,(1 + 0{\cdot}00367\,t)}\right).$$

The height p_2 observed by the underground barometer represents the joint effect of the natural air-pressure p and the depression h

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caused by the fan, the latter being subtractive when exhausting and additive when blowing;

or $$p_0 = p_2 - h.$$

Putting

$$\frac{p_0}{p} = \frac{1 + 0{\cdot}00367\, t_1}{1 + 0{\cdot}00367\, t}, = \text{num}\left(\log p_1 + \frac{s}{18363\,(1 + 0{\cdot}00367\, t)}\right)^{p_2 - h}$$

the required depression is given by

$$h = p_2 - \frac{1 + 0{\cdot}00367\, t_1}{1 + 0{\cdot}00367\, t}\,\text{num}\left(\log p_1 + \frac{s}{18363\,(1 + 0{\cdot}00367\, t)}\right),$$

p_2 being greater than the subtractive part of this equation when the fan is blowing, and smaller when it is exhausting, h will be positive in the first case and negative in the second.

The Author next gives the calculated results of the measurements upon the fan, when drawing air from the mine or from the surface. The effective duty expressed by the product of the volume drawn per second in cubic metres into the depression in millimetres was, at sixty revolutions per minute—

1. When drawing air from the surface, 516·75 cb. dm.
2. When drawing air from the mine, and having to overcome the resistances of numerous brattices and air-pipes, 220·48 cb. dm.

It follows, from the above figures, that the relations between the number of revolutions of the fan, gauge depressions, and velocity of current, only remain constant in a mine so long as the same arrangement of ventilation is maintained, or not materially altered; and further, that the effective duty of the Guibal fan diminishes rapidly with increase of pressure, and therefore it cannot be considered to be advantageously used when overcoming the resistances of long and narrow airways. In a final section the same method of calculation is applied to the discussion of the results obtained with other fans in neighbouring mines.

H. B.

On Separate Ventilation and its Cost. By B. R. Förster.

(Jahrbuch für das Berg und Hüttenwesen in Sachsen, 1882, p. 1.)

The Author gives the result of his investigations as a member of the Saxon fire-damp commission, as to the most advantageous means of ventilating workings in collieries that lie off the main air-courses. This is usually effected by taking off splints of the main current by brattices or analogous contrivances; but the Author objects to this method as weakening the main stream by the increased frictional resistance of the obstacles, and considers that it is preferable to provide ventilation for such points, either

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by supplying air above the pressure of the atmosphere from the surface directly, or by separate mechanical means without regard to the main ventilating current, which thereby, instead of being diminished, is augmented by the extra volume of air after it has accomplished its special duty. This may be done in several ways, that of allowing air at twice or three times above the ordinary atmospheric pressure to flow freely from the end of a pipe into the face of the workings being the simplest, but at the same time one of the most expensive methods, as the whole of the mechanical work expended in compression is lost, with the exception of that consumed by the frictional resistance of the pipes, the loss of pressure being expressed by the formula,

$$z = \frac{76}{10^{10}} \cdot \frac{l}{d} \cdot \delta \left(5 + \frac{1}{d}\right) \cdot u^2 \cdot 10{,}344,$$

where z = loss of pressure in millimetres of water; l = length, and d = diameter of pipe in metres, u = velocity of current per second in metres, and δ = weight in kilograms of a cubic metre of compressed air at the temperature of the mine, taken at 20° Centigrade.[1]

The values found by the above formula, and the diameter of pipe necessary to convey particular volumes of air under different conditions of pressure and velocity, are given in a tabular form, from which it appears that, although at high velocities the loss of pressure by friction is very large, especially with small pipes, in most cases the amount of such resistance is trifling, and bears but a small proportion to the work done in compression. In order to utilise this power, two methods have been adopted by the Author at the Royal colliery at Zaukerode. In the first, a jet of compressed air is supplied to a Körting blower, placed in the mouth of the drift to be ventilated, which by lateral inspiration supplies a volume of air to the working face from 5 to 6·6 times as great as that of the compressed air expended, according to the pressure of the latter. A better method is to allow the air to work a compound engine, which drives a Root blower in the mouth of the level, the increased volume so obtained being from 26½ to 31 times that of the air expended. A third method suggested is to take a supply of air directly from the main ventilating fan by a special tube; this, however, is only feasible within very narrow limits, as the small pressure produced by large fans would necessitate the use of pipes of unmanageably large size, in order to supply air in useful quantities. At a higher pressure of, say about $\frac{1}{10}$ atmosphere, smaller pipes would suffice; but as such a pressure could scarcely

[1] According to G. Schmidt ("Dingler's Polytechnische Journal," vol. ccxxxviii., p. 441), this formula agrees closely with Stockalper's experimental results upon the motion of air in pipes at the St. Gothard tunnels. It also agrees fairly with Schillings's data as to the loss of pressure in gas mains.

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be obtained from a single fan, it would be necessary to get it up gradually by two or more, placed one behind the other.

This principle has been very successfully adopted at the western end of the Arlberg tunnel, where three fans are employed in one series, and, working at about a third of their full power, supply 172 cubic metres of air at 1,300 millimetres water pressure, at a distance of 1,300 metres, which length will ultimately be increased to 5,000 metres, requiring a pressure of nearly half an atmosphere. A final plan, that of electric transmission of power, is represented by only a single example at Blanzy, although another is under construction by Messrs. Siemens and Halske for the Author. A small steam-engine of 4½ to 5 HP. drives a primary dynamo-electric machine; at the surface the current produced drives a similar secondary machine, placed underground in connection with a fan which will distribute the air to several workings near each other. At Blanzy a copper-wire cable is used as a conductor, but in this case it is intended to use steel-wire ropes that have been worn out in drawing coals.

As regards the cost of supplying air by the different systems noticed, a table is given showing the capital outlay required; the size of air-pipes; the cost per cubic metre supplied, and that of a given quantity—25, 50, and 100 cubic metres per minute—for a whole year. The following are the figures obtained for 100 cubic metres per minute. The use of steam as a motive power, at a cost of £12 10*s.* per gross HP. per annum, is assumed, which is higher than that paid at the Author's mine, where the cost is only about £8.

I. Compressed air at 3 atmospheres excess pressure; velocity of current 10 metres per second, escaping at full pressure from the air-pipe, 230 millimetres diameter, cost £9,235 per annum. The same using a Körting blower, and pipes 89 millimetres in diameter, £1,510. The same using a compound engine, Roots blower, and pipes of 50 millimetres, £365.

II. Branch current taken from main fan pressure, 0·001 atmosphere, or 10 millimetres water gauge; 2 metres per second velocity of current, pipes 1,030 millimetres diameter, £210. This, on account of the low velocity of current and the large size of pipes, would be practically useless at the distance of 1,000 metres from the fan.

III. Current produced by a special high speed fan at surface, $\frac{1}{40}$ atmosphere, or 250 millimetres pressure, velocity per second 6 metres, pipes 585 millimetres, cost £380.

IV. Current of 10 metres per second at $\frac{1}{10}$ atmosphere, 1,033 millimetres pressure, pipes 454 millimetres, produced by a series of two or three fans, or a cylinder blowing engine. The cost in the first case is £725, and in the second £870 per annum; or where the pressure is increased to ¼ atmosphere, £1,510, and £1,935. These are, however, only approximations, from very restricted data.

V. Electric transmission of power to mine ventilators working at low pressure; no pipes required; old pit ropes used as con-

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ductors, estimated at £180 per 1,000 metres; cost, £330 per annum.

VI. Hydraulic transmission of power to underground ventilating fan, using 48 millimetres pressure pipes, and force pump driven by steam-power, cost, £355 per annum, which would be somewhat reduced when a natural head of water could be obtained.

H. B.

The Use of Iron in Tubbing Shafts and Lining Drifts.[1]

By the Engineers of the Société John Cockerill.

In order to provide for the economical working of their Collard colliery, 307 hectares (758 acres) in extent, the Cockerill Company decided to abandon three of the four existing shafts; to enlarge the Marie shaft to 4·50 metres (14 feet 9 inches) diameter, and to put down a new shaft of the same diameter, to be called the Cécile, on the site of one of those that were abandoned. As this last-named work was one of great difficulty, it was found necessary to first fill up the old pit with ashes and shale in small pieces.

While the Marie shaft was lined with brickwork in the ordinary way, two bricks thick, a new system of iron tubbing was adopted for the Cécile shaft; and it is this system, with a similar application of iron to horizontal drivings, and their cost as compared with the ordinary methods, that constitute the object of this notice.

Iron Tubbing for Shafts.

The Cécile shaft is sunk to a depth of 523 metres (571 yards), the first 26 metres (28½ yards) being lined with masonry, so as to support the foundations of the buildings and engines on the surface. As the strata did not afford a solid bed for this masonry, it was laid upon a strong oak framework, from which also was suspended the first iron ring. The rings consist of four channel irons, 200 millimetres high, 58 millimetres wide, and 15 millimetres thick (8 inches × 2½ inches × nearly ⅝ inch), connected by cast-iron fishplates fitting in the channel, and secured by four pins to each fishplate. The top ring is suspended from the oak framing, and the rings are connected together by eight vertical bars of channel iron, 100 by 50 millimetres (about 4 × 2 inches), turned up at each end and secured by bolts and nuts. The rings are 1 metre (3 feet 3 inches) apart, for a depth of 127 metres, and 0·9 metre (3 feet) afterwards, and the space between the rings is closed by oak spiles 5 centimetres (2 inches) thick. The frame-

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[1] The original, with explanatory drawings, will be found in the Library Inst. C.E.

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work of the partition of the shaft consists of iron joists, in which a saving of one-third the cost of timber has been effected.

The weight of each ring is 1,080 kilograms (1·063 ton); and the total cost per metre (1·0936 yard) run, including labour, is 360 francs (£14 8*s*). As compared with the brick-lined Marie shaft, the Cécile, sunk in one-third the time, shows a saving under four heads, viz. (1) Expenses of sinking, timber, compressed air, coal, &c.; (2) Supervision and labour of engine-drivers, stokers, &c.; (3) A smaller amount of excavation beyond the final diameter than that required by brickwork; and (4) The being able to dispense with the temporary timber lining required with brickwork.

Iron Supports for Driving.

A modification of the above system has also been employed with success for supporting the roof of mine workings. Rejected railway bars are bent into the form of the cross section of a tunnel. Formerly, three rails were used to constitute each ring; but now only two are employed, with the fish-joints occurring at the sides, at a convenient height for screwing up the nuts. The rings are connected by tie-rods to keep them vertical and at an equal distance, about a metre (1·0936 yard) apart. The bottom rails also serve as sleepers for the tram-rails. The space between the rings is closed by spiles in the usual manner.

In October, 1870, a long and troublesome cross-cut was chosen for a trial of this system in its primitive form, as compared with the ordinary timbering. Seventeen rings were put up, a metre (1·0936 yard) apart, followed by 50 metres (54 yards) of timbering; and then came a second series of four iron rings, followed by another 50 metres of timbering. At the end of seven years, the spiles in the iron portion had been renewed every year; and three fractures had occurred owing to the thrust of the strata, but they were repaired with fish-plates on the spot; at the same time, the tramway had been rectified once. The timber portion, on the other hand, had been entirely renewed every year, and the tramway had been rectified thrice yearly.

Although the first cost of the iron support to the roof was 60 francs per lineal metre run, as compared with 24 francs for the timber, the maintenance of the former cost only 8 francs (6*s*. 6*d*.) per metre run per annum, against 28 francs (£1 2*s*. 6*d*.). But a cross-cut is required to stand twenty years, ten for hauling, and another ten for ventilation; and, taking this period for comparison, the iron support shows a saving of 1,820 francs (£72 16*s*.) per annum, over the timbering, if maintenance as well as first cost be taken into consideration. Half the labour is saved, because two iron rings can be put up in a shift of ten hours against only one timber frame.

J. W. P.

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On Copper-Smelting in the Bessemer Converter. By A. TAMM.

(Berg- und hüttenmännische Zeitung, vol. xli., p. 180.)

After noticing the original experiments of Jozza and Laletin at Wotkinsk, in the Ural in 1867, and those of Hollway, the Author described the working of Manhes' patented process at the patentee's works at Eguilles, near Avignon. The ores smelted are brought from Spain, Portugal, and Northern Italy; they consist mainly of copper pyrites, with quartzose vein stuff and some carbonates, and when mixed, so as to yield from 12 to 15 per cent. of copper, are smelted in low blast furnaces for coarse regulus of 33 per cent. produce. The Bessemer furnace slags used as flux consist essentially of basic silicates of iron, with from 4 to 5 per cent. of copper. The coarse regulus is converted into black copper by one operation in a Bessemer converter, but the latter is so placed that it cannot directly charge from the blast furnace, and it is therefore necessary to remelt the regulus in a cupola with an expenditure of 7 per cent. of its weight of coke. The converter, which tips in the ordinary way, and has a fixed bottom, is about 2 metres high and 1·40 metre in diameter. The lining is a mixture of sand and clay 300 millimetres thick at the bottom, 250 millimetres in the sides, and only 60 millimetres in the neck. The tuyeres, from twenty to eighty in number, are placed in a single ring about 150 millimetres above the bottom. These are 12 to 15 millimetres in diameter, but become wider by the waste of the lining in use. The operation is conducted as follows:—The converter, after heating with coke for about two hours, is turned down and receives a charge of about a ton of molten regulus, forming a bath about 300 millimetres deep. It is then turned up, and the blast, at about half an atmosphere pressure, is introduced. In the first stage of the operation sulphide of iron burns, giving a bright yellow flame with sparks, which continues until the residue is nearly pure copper sulphide. The flame then drops to a less brilliant one, of deep yellow tint without sparks, until the copper is reduced to the metallic state, when it becomes white and clear, sometimes with a green tinge at the edges; but this only happens when there is carbon in the furnace, so that carbonic oxide is produced. When the sulphurous acid vapours have disappeared the converter is turned down, and the contained slag and metal are run out, the latter being received in cast-iron chill moulds. Occasionally a small quantity of undecomposed copper sulphide is found adhering to the ingot first caught, and is separated by suddenly cooling the latter in water from a red heat. The products are crude copper of 97, and occasionally 98 and 99, per cent. fineness and slags, with 4 to 5 per cent. of copper, which are passed through the regulus furnace. The rise of temperature from the combustion of iron and sulphur is very considerable, and the bath is superheated to a considerable extent, as is apparent in the temperature

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of the products. The operation may be intermittent, if necessary, for a few minutes without endangering the result. The blowing lasts about half an hour, when twenty tuyeres are used, and a few minutes less with eighty. The scorification of the iron is entirely effected by the silicious lining of the converter, which requires to be renewed after about eight charges have been blown. The addition of quartz to prevent the lining wearing too rapidly is not practised, as it is found to chill the slag by the local cooling. When the lining is burnt out the converter is cooled by playing a stream of water upon it for eight hours, when a workman creeps in and rams it up with the mixture of sand and clay to the proper shape.

In order to work continuously three converters are required, in which sixteen charges are blown daily, and 5 tons of crude copper are produced. The number of men employed is twenty. The cost per 100 kilograms does not exceed 20 francs (£8 per ton), and the loss of copper is below 1 per cent. of that contained in the regulus. In September 1881, the process had been at work continuously for about six months. It does not appear to be applicable with advantage to regulus containing less than 20 per cent. of copper, and is therefore inapplicable to cupriferous iron pyrites. When a regulus of the kind treated can be procured, and water power is available, as is the case at Eguilles, the method offers great advantages in the saving of full time and labour, as compared with the ordinary method of concentration by alternate calcination and fusion, as it produces coarse copper from the ore in a few hours, while several days are required by the older method. The product is also of better quality, arsenic and antimony being volatilized during the blowing, and it may therefore be regarded as partially refined.

H. B.

On Variations in Weight. By M. MASCART.

(Comptes-rendus de l'Académie des Sciences, Paris, vol. xcv., 1882, p. 126.)

The method employed was to measure the height of a column of mercury which is in equilibrium with a gas at constant temperature. A sort of siphon barometer was used, the gas in the short branch being carbonic acid, at a pressure sufficient to support a column of mercury 1 metre in height. The temperature was kept uniform, the level of the mercury was seen by reflection on a gilded surface, and the hundredth part of a millimetre could be thus read. To submit the method to a decisive trial, the empirical relation existing between the apparent heights of the mercury and the temperature was determined by a series of experiments in a laboratory at the College of France; the instrument was then set up at a height of 180 metres, and afterwards taken back to the laboratory. The mean difference of the readings was 0·027 millimetre. Calculation shows that the variation in the altitude

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of the mercury between the two stations should have been from 0·02 millimetre and 0·03 millimetre, that is to say, a quantity not greatly above the limits of error of the instrument. The Author proposes making further trials with greater differences of elevation, as he considers that it permits of observations being made with as much ease as with the pendulum.

On the occasion of the communication Mr. Boussingault explained that he had endeavoured to discover whether there were variations in gravity from day to day, by making similar observations near the equator; he had, however, failed to observe such variations.

E. F. B.

On the Absorption of Heat by Gases, and a method depending thereon for determining the amount of Carbonic Acid Gas in the Atmosphere. By H. Heine.

(Annalen der Physik und Chemie, No. 7, 1882, p. 441.)

A special interest attaches to the absorption of heat by carbonic acid gas, both on account of its marked absorption of dark rays, and because as a constituent of the atmosphere it effects the chief part in the atmospheric absorption of the solar heat. The method employed in the experiments was substantially that used by Professor Röntgen, but the extension of it to the determination of the amount of carbonic acid in the air is due to the Author.

The apparatus, of which the Author gives a detailed description, consists essentially of four parts:—

1. A highly polished brass tube or receiver, with one end closed by a brass plate, and the other by a polished plate of rock salt. This receiver contains the mixture of the gases, whose absorptive power is to be measured.

2. A Bunsen burner as the source of heat, with its flame protected by a chimney, surrounded by a water vessel with an aperture opposite the rock-salt plate. The pressure of gas in the burner can be regulated, and suitable screens are provided for cutting off the whole or a portion of the radiant heat.

3. A tube, provided with stop-cocks, connecting the receiver with a chamber, in which the gases can be mixed in the required proportion.

4. A second tube, connecting the receiver with a self-recording pressure-gauge for measuring the increase of pressure due to the absorption of heat.

After discussing the possible causes of error and the extent to which they can be avoided or corrected for, the Author gives first the results of experiments on different mixtures of carbonic acid and air. The temperature of the mixture before exposure to the radiation was read by a thermometer placed in contact with the receiver; and the increase of pressure, which is a measure of the

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heat absorbed, is expressed throughout in millimetres of water, and reduced to an initial temperature of 22° Centigrade.

Percentage of CO_2.	Temperature of the Gases.	Pressure in Millimetres of Water.	Height of the Barometer reduced to 0° Centigrade.
	Degrees C.	Millimetres.	Millimetres.
100·000	22·6	49·5	755·0
68·660	22·8	45·4	755·1
47·142	22·8	42·6	755·1
32·368	23·0	40·7	755·1
22·223	23·0	38·7	755·1
10·477	23·1	36·1	755·2
4·939	23·1	34·0	755·2
2·328	23·2	31·0	775·2
1·098	23·4	26·3	755·3
0·517	23·4	21·0	755·3
0·244	23·5	15·3	755·3
0·115	23·5	10·8	755·4
0·054	23·6	7·2	755·4
0·026	23·7	4·5	755·4
0·012	23·8	2·5	755 4
0·000	23·8	0·0	755·4

From this Table it is apparent that the absorptive power increases with the percentage of carbonic acid present in the air, but not in direct ratio, the increase being much more rapid for small percentages than for large.

The second series of experiments was on mixtures of hydrogen and carbonic acid. The results are given in the subjoined Table, the numbers in the several columns having the same significance as before.

Percentage of CO_2.	Temperature of the Gases.	Pressure in Millimetres of Water.	Height of the Barometer reduced to 0° Centigrade.
	Degrees C.	Millimetres.	Millimetres.
100·000	24·7	50·1	756·6
68·660	24·7	25·1	756·5
47·142	24·8	17·5	756·5
32·368	24·8	13·3	756·5
22·223	24·8	10·7	756·4
15·259	25·0	9·2	756·4
10·477	25·0	8·2	756·3
4·939	25·0	7·2	756·3
2·328	25·1	6·1	756·3
0·517	25·2	4·1	756·2
0·000	25·2	0·0	756·2

It is to be observed that the curve, having the percentage of carbonic acid for abscissa and the increase of pressure for ordinate, possesses the same characteristics as before, but throughout its length lies lower than in the case of air and carbonic acid. This, no doubt, is due to the high coefficient of conduction of hydrogen gas for heat.

To apply the method successfully to the determination of the amount of carbonic acid in air, it was important to trace the curve more carefully for percentages of carbonic acid between 0·02 and

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0·05, since these may be considered the limits between which the actual percentage must lie. The mean of a number of experiments gave the following results:—

7·4	millimetres	correspond	to a	percentage of	0·115
5·0	"	"	"	"	0·054
3·2	"	"	"	"	0·026
1·7	"	"	"	"	0·012

A series of fifty experiments, extending over four consecutive days, were then made on atmospheric air, deprived of its aqueous vapour by passing through a drying apparatus, and of its ammonia by phosphoric acid. The results for the first day gave a mean percentage of 0·025, with a maximum variation during the day of 0·005; for the second day a mean of 0·025, with a maximum variation of 0·007; for the third and fourth a mean of 0·026 and 0·027, with a variation of 0·003 and 0·002 respectively. For the first two nights the results were 0·031 and 0·024, with a maximum variation of 0·006 and 0·002. During the first day and night the sky was free from clouds, as was also the case on the second and third days. The second night was cloudy, and the fourth day wet. The experiments were conducted in a laboratory situated some distance from the town.

The Author concludes by recording the values found by other experimenters, and points out that the method is equally applicable for the determination of the percentage of aqueous vapour present in the air. E. H.

New researches on the Propagation of Explosive Phenomena in Gases. By Messrs. Berthelot and Vieille.

(Comptes-rendus de l'Académie des Sciences, Paris, vol. xcv., 1882, p. 151.)

The Authors have already shown[1] that explosive phenomena, in being diffused in gases, give rise to an explosive wave, resulting from a change both in the chemical and physical condition of the medium in which they occur; and that this wave has a velocity independent of the pressure, and of the diameter of the tubes above a certain limit.

They have experimented with a large number of mixtures of very different composition, as the velocity of each inflammable mixture is a true specific constant, the knowledge of which is of great interest, both as regards the theory of motion of gases and of applications to explosive purposes. Each experiment was repeated two or three times, and performed in a caoutchouc tube 40 metres long, 5 millimetres internal diameter, and of great thickness. The results of the most remarkable cases are given in five Tables. The velocity calculated by Clausius's formula is com-

[1] Minutes of Proceedings Inst. C.E., vol. lxviii., p. 348.

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pared with the measured velocity of the explosive wave, with the following results. With hydrogen the two velocities are nearly equal; for hydro-carbons and cyanogen, the theoretical is from 5 to 12 per cent. greater; for carbonic oxide it is 40 per cent. greater, and the formula is not applicable. The two velocities agree closely, even for gases formed with absorption of heat, which have very high combustion temperatures, such as cyanogen and acetylene, as also for varied proportions of the volumes of the combustible and oxygen, and for very unequal ratios of condensation in the combinations, or even the want of it entirely, as in cyanogen and ethylene.

The formula may also be applied to mixtures of hydro-carbons with hydrogen, and even with carbonic oxide, the hydrogen communicating to the latter mixture a law of detonation similar to its own. Mixtures in which the final composition is the same satisfy the law, except in the case of carbonic oxide; as also do those in which an inert gas is mixed with the combining gases, except in the cases in which the mixtures approach the limit where detonation is not diffused.

Finally, the velocity of translation of the gaseous molecules, preserving the whole of the *vis viva*, which corresponds to the heat disengaged by the reaction, may be regarded as a limit representing the maximum velocity of diffusion of the explosive wave. But this velocity is diminished by contact with gases and foreign bodies, as also when the mass ignited in the first instance is too small, or cools too rapidly through radiation.

E. F. B.

The Vaporization of Metals in Vacuo. E. Demarçay.

(Comptes-rendus de l'Académie des Sciences, Paris, vol. xcv., 1882, p. 183.)

The object of the experiments was to examine whether a sensible volatilization of metals could be obtained at low temperatures by diminishing the pressure, and still more so in vacuo; and this was found to be the case. Only the most volatile metals have, so far, been employed, such as cadmium, zinc, antimony, bismuth, lead, and tin; but in all instances a large deposit of the metal was obtained on the cooled end of a U tube.

E. F. B.

On an Apparatus for maintaining the Flow of Gas from a Receiver at a Constant Pressure. By Jules Ville.

(Journal de Physique, July, 1882, p. 321.)

In practical work there is sometimes occasion to maintain the pressure constant in a receiver from which gas is flowing. The Author describes an apparatus designed by him for effecting this

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automatically. The apparatus is placed between the receiver and a reservoir of gas, in which the pressure is greater than that required in the receiver. As the pressure in the receiver diminishes from the outflow of gas the regulator allows a quantity of gas, sufficient to compensate for this diminution, to flow from the reservoir into the receiver. The regulator consists of a mercury manometer of special form. A cylindrical box of iron has a copper cover hermetically attached. At one side of the cover there is an outlet provided with a stop-cock A; in the centre there is an aperture with a copper mounting, which supports an iron tube reaching within 0·01 millimetre of the bottom of the box. Along the axis of the tube is a nickel-plated wire, supported by an insulating and air-tight stop of caoutchouc, through which it can be screwed up or down, so as to regulate the distance of its extremity from the mercury in the bottom of the manometer. Communicating with the interior of the central tube is a passage leading direct to the receiver and provided with a second stop-cock B. The stop-cock A connects the manometer with a valve worked by the armature of an electro-magnet. The valve communicates with the receiver and the reservoir of compressed gas through passages also provided with stop-cocks C and D.

The height of the mercury in the manometer is first regulated to the constant pressure, which it is desired to maintain, by admitting gas through the cock A; the nickel-plated wire is then lowered to within $\frac{1}{4}$ millimetre of the mercury and the cocks B, C, and D are opened and A closed. As the gas flows from the receiver and the pressure diminishes, the mercury rises in the central tube of the manometer and makes contact with the point of the wire. This completes a galvanic circuit through the electro-magnet, which draws up its armature and opens the valve, permitting gas to pass through C and D from the reservoir into the receiver. In the inner tube of the manometer, being in direct communication with the receiver, the pressure immediately rises and the mercury falls, breaking contact and allowing the valve to close.

The whole action is so nearly instantaneous that the pressure in the receiver remains free from sensible variation. It is indispensable to maintain an excess of pressure in the reservoir, and the strength of the electro-magnet must be proportioned to the excess. The sensibility of the apparatus is measured by the play allowed to the mercury before making contact. This has no need to exceed $\frac{1}{4}$ millimetre of mercury. The apparatus can be used for any pressure by making the walls of the manometer and tubes of a suitable strength.

E. H.

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The Filtration of Vapours by Möller's Process.

By Dr. Fr. Böckmann.

(Zeitschrift des Vereines deutscher Ingenieure, vol. xxvi., 1882, p. 343.)

Various methods have been tried for mechanically separating fluids from vapours. Dr. Möller has succeeded in constructing filters which fulfil the above purpose satisfactorily. These filters consist of perforated tubes, covered on the outside with several thicknesses of fine wire gauze, and arranged in a vertical position in a suitable chamber. The vapour mixed with suspended fluid has free access to the outside of the tubes, but the vapour only passes through, and the separated fluid falls to the bottom of the chamber.

These filters have been successfully used for various purposes, such as fractional distillation, the manufacture of coal-tar products, and the production of dry steam. In the latter case the filter-tubes are dropped through a tube-plate placed in the steam-dome, and hang down into the steam-space.

The filter area must be so large that no perceptible loss of pressure occurs, and the merit of the invention consists in utilizing the simple principle that vapours and gases may be filtered as well as liquids, provided only that the filter area is large enough to admit of the vapour passing at a very low velocity. By the plan adopted a large amount of filtration-area is obtained in a small space. W. P.

The Waltenhofen Phenomenon and the Demagnetisation of Iron Bodies. By Felix Auerbach.

(Annalen der Physik und Chemie, No. 7, 1882, p. 554.)

From his own experiments and also from those of Wiedemann and Fromme, the Author has shown in a previous Paper that the magnetisation of an iron body at any time is dependent not only on the then magnetising force, but is a function of all previous magnetisations to which it has been subjected. This function is independent of the time the magnetising forces have acted, provided there have been no sudden changes. In the latter case the final magnetisation is greater or less than that resulting from a gradual change according as the transition is from a less to a greater, or from a greater to a less force. As a particular case, when a magnetising current is suddenly broken, the permanent magnetism is less than if the current had been gradually diminished—a phenomenon originally observed by Mr. von Waltenhof.

In his previous communication the Author had described a method for completely demagnetising iron, and which subsequent experiments have proved very successful. It consists in subjecting

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the iron to alternately positive and negative magnetising forces, diminishing in magnitude down to zero. For example, taking a bar of magnetic moment P, it is exposed to forces $-J$, $J-e$, $-(J-2e)$, . . . down to $J-Ke$, where $(K+1)e = J$. The smaller e the more perfect is the demagnetisation. The proper value of J necessary for complete demagnetisation depends on the magnitude of the previous forces to which the bar has been subjected, but in cases where the magnetic history of the bar is unknown, it is safest to take J as large as conveniently possible.

It is known that a single magnetising force will reduce a bar to an apparently non-magnetic state, *i.e.*, it behaves with regard to other bodies as a non-magnetic body; but if a bar, demagnetised in this way, is subjected again to magnetising forces it is found to possess polarity, its moment not being equal and opposite for equal and opposite forces. This "latent magnetism," as it is called, can be eliminated by hammering or heating to a red heat, but not so completely as by the Author's method.

The method is also applicable for determining the normal or true value of the magnetisation corresponding to any force P. The bar must be subjected to forces alternately greater and less than P and gradually approaching it in value. It is very remarkable that a curve of magnetisation determined by this method does not show the point of inflection observed by Wiedemann and others in the case of a bar magnetised in the ordinary way.

E. H.

A Selenium Photometer. By E. Boistel.

(La Lumière Électrique, July 1882, p. 38.)

It is well known that on the exposure of selenium to light, its electrical resistance diminishes. This effect does not appear to take place for rays in the dark part of the spectrum, but reaches a maximum for rays between the yellow and the green. It is consequently only between lights of the same colour that a satisfactory comparison can be made by observing their effects on the resistance of selenium exposed to their action. A photometer based on this principle has recently been constructed by Messrs. Siemens and Halske of Berlin.

A horizontal copper tube, 3 centimetres in diameter and 15 centimetres long, is mounted on a stand fixed at one end of a horizontal graduated bar. The stand with the copper tube attached is movable about a vertical axis, and is provided with a levelling screw. One end of the tube is fitted with a metallic diaphragm with a central circular aperture, and the other with a mounting carrying cross wires. This latter can be removed and replaced by a short horn box, containing a plate of selenium specially prepared. The plate is protected from the light by a valve, which can be opened by a button outside the tube. At two opposite points of the plate wires are attached, which connect it through a galvano-

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meter to the battery. One of Thomson's portable mirror reflecting galvanometers is the most suitable for the purpose.

In making an observation the tube is turned towards the light to be measured, which is then centered by means of the cross wires. The diaphragm and the mounting carrying the cross wires are removed, and the latter replaced by the selenium plate. The galvanic circuit is completed, and the plate exposed to the light. After noting the deflection of the galvanometer, the tube is turned about its vertical axis until it is in line with the graduated rod. A standard candle or lamp slides on the rod, and its distance from the plate is adjusted until the galvanometer deflection is the same as before. The intensity of the lights are then proportional to the squares of their respective distances from the plate. It is found that an exposure of very short duration is sufficient to effect the change of resistance.

E. H.

Air-Thermometer Independent of Barometric Pressure.

By ALBERT A. MICHELSON.

(American Journal of Science, August 1882, p. 92.)

The instrument consists of a glass bulb and stem, the former about 1½ inch, and the latter 0·079 inch, in interior diameter. The bulb contains dry air at a pressure of 4 inches of mercury, and the air is separated from the upper portion of the tube by a column of mercury 4 inches in length. The mercury remains above the air, notwithstanding the large diameter of the bore, owing to the resistance to deformation of the meniscus. The space above the mercury is a vacuum. Thus the pressure of the air in the bulb is constant, and is equal to that of the column of mercury above it. If the bore of the stem is not of uniform section the length of the column will change; but this length is easily read off, and gives at once the true pressure. The pressure need not be limited to 4 inches, but if it be much greater the instrument becomes inconveniently long.

The only precaution to be observed, beyond what is used in the ordinary mercury-thermometer, is that the stem must be kept vertical.

On the Actinic Transparency of Optical Glass.

By COUNT DE CHARDONNET.

(Journal de Physique, July, 1882, p. 305.)

The Authors, while engaged in photographical researches on the ultra-violet rays of the spectrum, found it necessary to determine the absorption due to the various qualities of glass employed. Although no rigorous laws were arrived at, still the following

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results, deduced from the discussion of a large number of "negatives," may be considered useful. The characteristics depending on the quality of the glass are, firstly, the shortest wave-length which is transmitted, even through very thin plates, and with prolonged exposure; and, secondly, the minimum thickness beyond which the absorption does not diminish [6 mm. (0·24 inch) for homogeneous English crown-glass]. Starting from this limit, the shortening of the spectrum, reckoned along the scale of wave-lengths, seems sensibly proportional to the thickness of the medium. The following tabular results were obtained with plates 6 mm. thick, and after prolonged exposure:—

Description of Glass.	Wave-length, below which the intensity of the rays rapidly diminishes.	Wave-length, beyond which all action on Bromide of Silver ceases.
	Millimetre.	Millimetre.
Extra heavy flint (Feil-Guinand, No. 1,505) . .	·000355	·000350
Heavy flint („ „ „ 1,481) . .	·000340	·000330
Light flint („ „ „ 1,472) . .	·000325	·000316
„ „ (Messrs. Chance)	·000320	·000310
Light crown („ „ Nos. 1,478 & 1,502)	·000315	·000308
St. Gobain crown		
Soft crown (three specimens from Messrs. Chance)	·000305 to ·000315	·000303

It appears, therefore, that the English glass is the most transparent.

The absorption of any given optical system, if defined as the shortening of the spectrum, is due in part to the glass of least transparent quality and to the sum of the effect proportionally introduced by the rest of the system. The following Table will give an idea on this point:—

Description of Optical Combinations.	Shortest Wave-length on the Negative.
	Millimetre.
6 millimetres of heavy flint + 6 millimetres of crown (Feil-Guinand)	·000335
6 „ „ „ „ + 18 „ „ „ „ „	·000333
6 „ „ light „ + 6 „ „ „ „ „	·000324
6 „ „ „ „ + 18 „ „ „ „ „	·000315
6 „ „ „ „ + 6 „ „ „ (Chance) .	·000310
6 „ „ „ „ + 18 „ „ „ „ .	·000315
18 „ „ „ „ + 18 „ „ „ „ .	·000327

Now that the ultra-violet rays are playing such an important part in physical and astronomical research, care should be taken to use only light white flint-glass, and to reduce as far as possible the thickness of lenses and prisms. F.

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On the Methods employed for the Determination of the Ohm.

By G. LIPPMANN.

(Journal de Physique, July 1882, p. 313.)

The determination of the electro-magnetic absolute unit of resistance depends on the production of an electromotive force by induction. In most cases the induction gives rise to a variable current, and hence a complication is introduced by the induction of the current on itself. This necessitates a correction, the degree of accuracy of which it is difficult to estimate. In the recent experiments of Lord Rayliegh and Dr. Schuster by the British Association method this correction amounted to 8 per cent. Moreover the resistance of a conductor of finite section, as is the case with a metallic wire, is only properly defined for constant currents, when the intensity of the current is the same for all points of a section of the conductor. Helmholtz has shown that with variable currents the intensity is greater at the periphery than at the centre. Hence the employment of constant currents is much to be preferred.

(1.) The first method satisfying this condition is due to Mr. Lorenz (1873). He employed a circular disc of copper rotating about its axis which is placed parallel to the lines of force produced by a circular coil concentric with the disc and traversed by a constant current. The electromotive force due to the induction will be along the radii of the disc, and can be received by rubbers placed at the centre and circumference. If i be the intensity of the current in the bobbin, w the angular velocity of the disc, the radial electromotive force is $Cw\,i$, where C is a constant, which can be determined by calculation. The current i traverses the resistance r, whose absolute value is sought, and produces a difference of potential between the extremities equal to $r\,i$. By connecting the rubbers to the ends of r in such a manner as to oppose the electromotive forces the velocity w can be regulated until the two are equal, the equality being determined by a galvanometer placed in the circuit, which at the moment of equality will give no deflection. Then

$$C\,w\,i = r\,i;\ \text{whence}\ r = C\,w.$$

The only difficulty presented in this method is the calculation of C, which depends on elliptic integrals, which cannot readily be evaluated to a known approximation.

(2.) The induction of the earth is also available for the determination of the ohm with constant currents. A vertical frame carrying a coil of wire is caused to rotate about a vertical axis with n revolutions per second. The circuit of the coil is not closed, but its extremities make contact at the moment of maximum induction with wires leading to the ends of the resistance r to be determined. In one of the leads Sir W. Thomson's astatic galva-

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nometer is placed and used as a galvanoscope. A constant current is maintained through r and measured by a tangent galvanometer. As the disk rotates an electromotive force is induced in the coil, which is opposed to that of the current i. The latter is then varied by means of a rheostat placed in the battery-circuit until the galvanoscope gives no deflection. If S be the effective area of the coil, K the constant of the tangent galvanometer, and a its deflection, then,

$$r = \frac{2\pi n S}{K \tan a}.$$

The quantities to be measured are precisely those occurring in the British Association method, but the correction for self-induction is avoided. This method has previously been suggested by Carey Foster and Maxwell.

(3.) The induction of terrestrial magnetism can also be used for obtaining a constant electromotive force. A copper disk similar to the one employed by Mr. Lorenz is rotated about an axis parallel to the compass needle. A radial electromotive force is produced, which can be received by rubbers placed at the centre and circumference. Using a similar arrangement to that described in (2), the resistance r is given by the equation—

$$r = \frac{n S}{K \tan a},$$

where S is now the area of the disk.

The electromotive force produced in this manner is very small, but by using a Thomson's galvanometer a degree of accuracy of 1 in 6,000 can probably be obtained.

E. H.

Bichromate Batteries. By COUNT DU MONCEL.

(La Lumière Electrique, May, 1882, pp. 433–437.)

This is an exhaustive study of several new modifications of the bichromate battery, the chief results being obtained with the dry or solid salts of Messrs. Voisin and Dronier, by which the battery can be charged with the simple addition of water, and making it much more adaptable to practical use. The salts are used in the proportion of one-fourth of the weight of the water. The constitution is, for the sulphate of potash salt: water, 80 grammes; sulphuric acid, 11·80; bichromate, 5·20; sulphate of potash, 3·00 grammes. When sulphate of soda is substituted for the potash, the proportion of bichromate is 5·40, and of sulphate of soda 2·80 grammes. The salt is thus prepared: the sulphate is dissolved by means of heat in the sulphuric acid, and the bichro-

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mate slowly added. Solidification ensues on cooling, and the mass before complete cooling is cast into moulds. The use of this salt appears to the Author to be advantageous for telegraphic purposes as applied to the bichromate sand-battery.

P. H.

Progress in Secondary Batteries. By Aug. Guerout.

(La Lumière Electrique, June, 1882, pp. 584–6.)

Since the modification by Mr. Faure of the Planté secondary battery has drawn attention to the industrial applications of this apparatus, very numerous forms of accumulators have been introduced. The journal "La Lumière Electrique" has from time to time described the accumulator invented by Mr. de Méritens,[1] that of Messrs. de Pezzer et Carpentier,[2] and of Mr. Sutton,[3] as well as the form given to the Faure battery by Mr. Reynier.[4] Some other arrangements have been more recently introduced, of which the chief are the new model by Mr. de Méritens, that by Mr. de Kabath, by Messrs. Sellon and Volckmar, and that by Mr. de Changy. In Mr. de Méritens' former accumulator, each lead electrode was formed like the leaves of a book; in the new arrangement each electrode is like a venetian blind, in which the strips are horizontal, very thin, and nearly touching, forming a complex plate 30 centimetres in height by 25 in width and 1 in depth. Each accumulator comprises only two electrodes, enclosed in a rectangular ebonite box.

Mr. de Kabath employs undulating bands, analogous to those described in Messrs. de Pezzer and Carpentier's accumulator, but with the undulations perpendicular and not oblique to the edges of the band. In this apparatus a wooden trough contains six or fourteen compound electrodes placed at a little distance from one another, the odd plates being connected together to form one electrode, and the even to form the other. Each electrode is thus composed of a hundred thin vertical bands, alternately plain and corrugated, placed beside each other to form a plate 8 to 9 centimetres wide, 40 centimetres high, and about 1 centimetre in depth. On the two greater surfaces, these layers of bands are held together by lead plates pierced with holes.

Messrs. Sellon and Volckmar have constructed their accumulators with plates of lead pierced with holes filled with spongy lead. The lead plates are 4 millimetres thick and distant from each other about 2 millimetres. The active part of the plate is thus constituted principally by the substance filling the holes; the plain parts

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[1] La Lumière Electrique, No. for 28 Sept. 1881.
[2] *Ibid.*, No. for 14 Dec. 1881.
[3] *Ibid.*, No. for 14 Jan. 1882.
[4] *Ibid.*, No. for 28 Dec. 1881.

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serve for support, participating in a certain measure in the electrochemical action.

Mr. de Changy employs masses of lead, not spongy, but made by a special process to have great surface for little weight. This process consists in casting the lead on to a cold surface, the metal thus suddenly cooled forming finely divided masses. Mr. de Changy places these masses in a vessel divided into two compartments by a porous partition.

All these new arrangements will accumulate a certain quantity of electricity, but no numerical results have yet been published. There is, in the opinion of the Author, reason to suppose that these are not the best methods of utilising lead for the accumulation of electricity. These inventors have sought to give a maximum surface for a minimum weight, and this would be right were the elements constructed as are those of Planté, in which all the surface is equally active; but in the new accumulators this is not the case. In the Faure cell the inventor has acknowledged that the action does not completely penetrate the oxide of lead; and this will evidently be true of electrodes of 1 centimetre depth, for it is a well known fact in electrolysis that when the electrodes are not plane surfaces, the action is chiefly produced on the parts of the electrodes nearest together. With the electrodes described, action will chiefly take place on the edges of the bands and the central portion of the mass remain inactive. With the flat plates pierced with holes it will be the plane portions of so thick a plate that will be imperfectly utilised because of insufficient penetration.

The Author then proceeds to describe the application of storage batteries to an industrial railway at the Bleachery belonging to Mr. Duchenne-Fournet, at Breuil-en-Auge.[1] There are two wagons, one containing ten boxes of Faure's battery of six cells (Reynier's type) each, the other an electric-motor capable of being put at will in connection with either the wheels of the wagon or with a reel on which the linen may be wound. The wheels can be stopped by a brake, the action of which is simultaneous with that of a switch, causing diminution of the current and rupture of the circuit when the wagon is stopped. Behind this motor wagon are six open wagons to receive the linen. The speed required is very low, but 12 kilometres an hour can be attained. Considering however the great weight (the accumulator wagon weighing 800 kilograms), a more economical utilisation of the electrical current would have occurred from using the rails as conductors; but the dampness of the bleach-fields through which the railway is run, and the complicated pointing existing rendering that course impracticable. Steam-motors were inapplicable for reason of damage to the linen goods from fire and soot.

P. H.

[1] Minutes of Proceedings Inst. C.E., vol. lxix., p. 503.

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On the Appearances of the Electric Arc in the Vapour of Sulphuret of Carbon. By Messrs. Jamin and Maneuvrier.

(Comptes-rendus de l'Académie des Sciences, Paris, vol. xcv., 1882, p. 6.)

Two parallel vertical carbons were used, one of which was movable at its base on a hinge, so that the two might be made to touch at the upper portion, and placed within the receiver of an air pump. A vacuum being made, no arc was formed, a few drops of sulphuret of carbon were introduced, increasing the pressure from 50 millimetres to 60 millimetres, when an explosion of light occurred incomparably superior to that of the ordinary arc. It was of a horse-shoe form, 50 millimetres high, with a flame above it, of a pale green colour. The brilliancy increases, so as to become intolerable from time to time, always followed by a total extinction of the arc.

Spectroscopically examined, it appears to have all the lines of carbon gases in combustion. The spectrum is very discontinuous; it consists of four channelled parts in the red, yellow, green, and violet; of these, the green is by far the most luminous. The experiment is remarkable for the extraordinary quantity of light produced, for the size of the arc, its colour, the composition of its spectrum, and the chemical actions which take place. It is not likely that it will ever be useful for lighting purposes, unless for lighthouses or distant signals.

E. F. B.

Telegraphy, its recent progress as shown at the International Exhibition of Electricity, Paris.

(La Lumière Electrique, May and June, 1882, pp. 449–452, 470–474, 498–499, 519–523, 544–546, 568–571, 592–594; July, 1882, pp. 62–64, 90–91.)

Batteries.—The Callaud battery, largely used in France, has the fault of depositing copper on the zinc, as is known. This is avoided in the batteries used by the Alsace-Lorraine Railway by a funnel of lead connected to the lead-plate forming the positive electrode. Mr. Gaiffe substitutes for the funnel a copper ring. Mr. Moser suspends between the zinc and the copper an insulated plate of zinc, which receives the deposits of copper produced by diffusion. The use of a diaphragm of parchment paper is due to Mr. Carré, who has since substituted a tissue coated with bichromatised gelatine, with considerable advantage in rapidity of construction. Mr. Samson replaces the copper strip coated with gutta-percha, of the Callaud battery, by a strip of enamelled iron. The Buschtehrad Railroad Company of Austria use the Kohlfürst battery exclusively, in which diffusion is prevented by a thin plate of porous porcelain resting on an inner rim in the jar. The

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zinc is conical, suspended with the apex lowest; the positive pole is formed of a piece of lead bent to S-shape. The zinc is immersed in a solution of sulphate of zinc or of magnesia. The cell is covered with an iron plate. A single charge is sufficient for six to eight months' work on important lines, and for ten to fourteen on less used lines.

The Leclanché battery possessed the defect that its internal resistance was much increased by the formation of insoluble oxy-salts of zinc on the porous vase. Mr. Leclanché has made two improvements in his battery which place it beyond criticism in this view. The depolarising mass is subjected to strong pressure, and the porous vase dispensed with; the oxy-salts are dissolved by 3 or 4 per cent. of bisulphate of potash added to the mass. The composition has been definitely fixed at 40 per cent. of peroxide of manganese, 55 per cent. retort-carbon, 5 per cent. gum-lac. The electromotive force is 1·5 Daniell. Another modification of the Leclanché battery consists in using a vase of vitreous clay pierced with numerous small holes, and platinised carbon, the latter depolarising very quickly, and increasing the electromotive force of the battery to 1·65 volts. Mr. Gaiffe employs alternate layers of retort-carbon and of binoxide of manganese to increase the depolarising surface. Mr. Howell, in the battery constructed by Clark, Muirhead and Co., places in an exterior jar of earthenware another earthenware jar, termed the "separator," in which are vertical slots. The separator contains the porous vase, in which is the zinc amalgamated and immersed in a solution of sal-ammoniac. Between the separator and the exterior vase is a carbon electrode, immersed in a mixture of graphite and binoxide of manganese, surmounted by a layer of sulphate of manganese, over which is poured diluted sulphuric acid. The electromotive force of this element is 2·14 volts; its internal resistance 5 to 6 ohms.

The Marié-Davy battery was abandoned by the telegraph administration, for the reason that the sulphate of mercury was found to be so very poisonous; but Mr. Beaufil's modification is used, and contains an inoffensive mixture of sulphate of mercury with powdered carbon and paraffin, the electromotive force being 1·5 volt.

In the nitric acid battery Mr. Delaurier substitutes a mixture of nitrate of soda and sulphuric acid, which produces the same effect. The Swiss telegraph administration still employ the Bunsen battery, modified by Mr. Nystrom. Sulphuric acid and a small quantity of bichromate are used for depolarising; the carbon-heads are plated, and the fittings of the terminals are in copper, sulphate of lead being produced with lead-heads, and the resistance thereby increased. Evaporation is prevented by placing on the cell a cover, from which are suspended the zinc and the carbon. The electromotive force of this arrangement is high and the resistance small. The Tommasi battery has a clay cylinder that contains the carbon raised to double the height of that for the

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diluted sulphuric acid and zinc. The porous vase also contains a bottle, pierced with a hole at the bottom and stoppered on top, filled with the same liquid. An ingenious system of siphons allows of renewing the liquid simultaneously in all the cells. The Cloris-Baudet battery has, fastened to the porous vase, two smaller porous vases, one containing bichromate crystals, the other sulphuric acid. The zinc is immersed in a solution of sea-salt, water, and vinegar. Mr. Chutaux's battery is employed in London at the Submarine Telegraph Company's office. The carbon is surrounded with fragments of the same substance, and the zinc with silicious sand. A small porous vase, held at the upper part of the cell, is surmounted by an inverted bottle containing a bichromate solution. The exciting liquid leaks through the small porous vase, moistens the mass, and drains off from the lower part into a second element arranged beneath the first, and thence into a receiving bottle. It will serve two or three times. The carbon is vase-shaped and surrounded by cardboard, which, under the action of the sulphuric acid, becomes pasty, yet does not appear to much increase the resistance. The electromotive force is about 2·2 volts. Morgan's litharge battery is arranged similarly to Callaud's battery, the litharge being kept down by its weight. The zinc rests in a solution of sal-ammoniac. The positive electrode is lead. The reaction produces lead, chloride of zinc, and gaseous ammonia, which is disengaged. Maiche's telegraph battery is composed of platinised retort-carbon and amalgamated zinc, obtained by putting some zinc into a small porcelain cup containing a little mercury. The cell is closed by an ebonite cover, to which is fastened a porous vase pierced with holes, and filled with broken carbon platinised. The cup containing the zinc is fixed to the cover by a strip of ebonite which descends two-thirds of the vase. The porous vase is only slightly immersed in the exciting liquid (sal-ammoniac) that surrounds the zinc, so that the hydrogen developed on the carbon is in contact with large air surface, whence it can absorb oxygen, and thus much reduce polarisation. The electromotive force is 1·25 volt, but the resistance is high.

Mr. Trouvé constructs portable Daniell batteries of plates of zinc and copper, with interposed sheets of bibulbous paper moistened with the sulphates of copper and zinc respectively adjacent to the plates of these metals. Mr. Desruelles substitutes asbestos for the bibulbous paper. Asbestos is not attacked by acids, and from its extreme capillarity offers very little resistance to the current.

Poles and Posts.—Desgoffe's pole is of sheet-iron, bent into two halves of the section of the pole, and the edges riveted to plate-iron running the length of the pole. The pole is set in a concrete block. A 6-metre pole costs 39 francs. The poles on the line from Paris to Juvisy support thirty-four wires, vary from 10 to 13 metres in height, and 200 to 300 kilograms in weight. A pole 18 metres high, to carry twelve wires, weighs 428 kilograms.

Oppermann's pole is of T-iron, is very simple, and will carry as many as eighty wires. The insulators are affixed to arms of

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angle-iron. A single pole costs 20 francs; a multiple pole 28 francs.

Delataille's pole has the cross-arms of square iron bolted to T-iron as in the preceding pole, but, instead of to the plane face, are passed through openings in the rib. A cross-arm of 1·25 metre carries four insulator bars, which are square in section, and tapped at the lower end, and fit into square mortices in the cross-arm, being fastened with screws. The pole is set in a concrete block 1 metre in height, 0·20 metre square on top face, and 0·20 × 0·50 metre lower face. The cost is not given.

Papin's pole is formed of four corner irons, completed by plates of sheet-iron riveted on. Lemasson's pole is similar.

Siemens' poles are too well known to call for description.

Insulators.—That adopted for the great lines in France is the double-bell, but without a hook to support the wire, which passes through a groove in the upper part of the insulator. Two vertical lugs hold the wire.

The Crighton insulator has a screw-thread at the upper part, in which is a vertical slot. The wire is put through this slot and jammed there by a small galvanised iron wedge; a small cap is then screwed over the top of the insulator to clamp the wedge and the wire.

Conductor-Wires.—The reporter finds nothing new in this section. In Germany coated wires are still used; the wire as it passes from the drawer being coated with linseed oil. The coating is effected by raising the wire to red-heat and plunging it into the oil.

In Belgium phosphor-bronze wire of 1¼ millimetre diameter is proposed to be largely used for telephone lines.

Subterranean Lines.—The Berlin-Halle line is described; the construction of this line has been detailed in these Abstracts, except the curvature and lengths of tubes enclosing the wires when other than straight work was met. At the curved parts tubes of about 1 metre length were provided with a bend of 11°. In sections of 400 to 500 metres no more than two curved tubes were employed corresponding to a total bend of 22°. In sections of 300 to 400 metres three tubes were used as a maximum, corresponding to a total bend of 33°. In sections of less than 300 metres a maximum of four tubes, corresponding to a total bend of 44°. Sometimes, to facilitate drawing, a drawing-box would be placed between two joint-boxes. When the angle at the drawing-box was not a multiple of 11°, the cutting of a curve-tube gave the angle desired.

The use of curves is unavoidable when a considerable angle is to be turned, but in longer and less sudden curves the bend may be gradually made at successive joints to a radius of curvature of 500 metres. In drawing, for equal bends, the curving of the conduit produces the same effect as a curved tube, and a curve of 100 metres gives the same bend as a curved tube. Passage from one line to a parallel alignment sometimes necessitates the use

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of two curved tubes placed with their curvature in opposite directions.

Drawing is effected in the first instance by a length of twine passed through each tube of the conduit as it is laid, the twine being used to draw in an iron wire, and this the cable. If the drawing is particularly hard, soapstone powder or talc is thrown on the cable.

The difficulties with the joints of iron pipes, and the cost and labour of drawing, have called attention to substitutes; and in Belgium the Delperdange system has promised well. These tubes have a slot throughout their length sufficiently wide to allow the cable to pass; closing is effected by a ⊥-shaped piece, the horizontal flanges entering the slot in the tube, and being pulled against the interior edges by a key driven through the rib or vertical flange. But lead-covered cables appear to afford the best solution of the problem. The article then describes the Borel-Berthond lead-covered cable and Mr. David Brooks's system; also the well-known circumstances of submarine cablework.

P. H.

An Electric Power-Hammer. By Marcel Deprez.

(La Lumière Electrique, July, 1882, pp. 53–54.)

The Author exhibited on the 15th June, at the Conservatoire des Arts-et-Metiers, Paris, an electric power-hammer, consisting fundamentally of a solenoid in sections. Let there be a hundred flat coils, of 1 centimetre each in depth, placed one on another to form a single solenoid 1 metre in height, and let each of the entering and issuing ends of the coils be connected to each other and to the segments of a commutator, as in a dynamo machine; then if two brushes (fixed to an insulating piece movable by hand) are placed at such a distance that the number of plates of the collector or commutator-segments is ten, the current can always be made to pass through ten coils, whilst the same distance is preserved, whatever their position on the commutator; and the motion of the brushes is equivalent to the motion of a solenoid having ten coils. With this arrangement, and the brushes in a given position, let a current be caused to flow through the apparatus, and a cylinder of soft iron placed within it; the cylinder will remain suspended in the solenoid constituted by the ten coils, and its centre of figure will be at a greater distance from that of the solenoid as the current is weaker. It will fall completely if the current has not strength above a minimum value. If the current be strong enough to maintain the distance of the two centres of figure much less than the fall of the cylinder, the latter will be in equilibrium, and if it be moved will require, as if it were suspended by a spring, the force to increase with the distance moved through. So that if the brushes are displaced the

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space of a plate or segment of the collector, the active solenoid becomes displaced to an equivalent amount, and the cylinder reproduces the movements given to the brushes by the hands of the operator. The current is never interrupted, nor modified in volume or direction. In the power-hammer as constructed, eighty coils are built up to a height of 1 metre, and the wire-ends brought out to a circular commutator. The iron cylinder weighs 23 kilograms, but when the current amounts to 43 ampères, and traverses fifteen sections, the lifting power developed is 70 kilograms, three times the weight of the hammer.

This power-hammer was placed, in derivation, on a circuit that fed also three Hefner-Alteneck machines [Siemens D_5] and a Gramme dynamo [Breguet P.L.]. Each of these machines made fifteen hundred revolutions a minute, and developed 25 kilogrammetres a second, measured on a Carpentier brake. All the apparatus worked with absolute independence; the generator was the double-wound machine [Mr. Deprez' system] used at the recent Paris Exhibition. In a later trial 50 kilogrammetres per second were developed at each of the four machines, whatever the number at work, and then the addition of the power-hammer in shunt-circuit did not much affect the working. The efficiency with six machines working independently from one generator, and each machine giving two-thirds of a horse-power, would be, with this system, $\frac{e}{E} = 0{\cdot}50$. P. H.

Electric Transmission of Power. By Aug. Guerout.

(La Lumière Electrique, July, 1882, pp. 34, 35.)

The electric transmission of power to a distance includes two cases that may be regarded as distinct: transmission to a great distance, and to a moderate distance. Transmission to a great distance necessitates, as Mr. Marcel Deprez has shown, the use of machines wound with fine wire, and by this means it may be effected with good efficiency. But to nearly the present time nothing has been done in transmission to a great distance, and even were this the impractical problem, transmission to short distances offers many applications. The Author cites the examples at the Belle-Jardinière, and at Messrs. Heilmann, Ducommun, and Steinlen's Exhibit at the Palais de l'Industrie. The former is an example of power-transmission that could not be effected by means of belting. A motor is situated in the cellar, and power is transmitted to the upper floors of a building to work sewing-machines. The latter was, as an exhibit, divided into two parts; in one division the generating machines were arranged in two rows and worked from a steam-motor, the other division included a workshop of machine-tools driven by two Gramme machines

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(type A). The connecting wires transmitted three HP., sufficient to work ten tools. A part of the current produced by the generating machines fed Werdermann-Reynier and Edison lamps to light the shop.

P. H.

Researches on the use of Crusher-Gauges for Measuring the Pressures developed by Explosive Substances.

By Messrs. SARRAN and VIELLE.

(Comptes-rendus de l'Académie des Sciences, Paris, vol. xcv., 1882, p. 26, p. 130, and p. 180.)

The special difficulties connected with researches of this character are due to the magnitude of the pressures and the rapidity with which they vary. For some years the crusher gauge of Captain Noble has been employed in France—in which a copper cylinder is crushed by the action of the gases; and the Authors employed one of these, in their study of the numerical value of the indications it is susceptible of giving. They first obtained the resistance of the cylinder, by crushing it slowly and progressively by small quantities, until it supports without permanent deformation a certain charge. The operation thus carried out gives the resistance of the cylinder corresponding to each crushing value. Between the limits 1,000 and 3,500 kilograms, the resistance of the cylinders may be expressed as a linear function of the crushing force, from which a table may be formed.

There are two limiting cases for which the value of the maximum pressure developed by the explosive is in simple relation with the indications of the table. The first, in which the pressure develops so slowly, and the mass of the crusher piston is so small that its inertia may be neglected; and the second, in which the crusher piston moves under constant pressure without initial velocity. To determine the particular cases in which the apparatus may be considered as working near its limits, and to establish a mode of calculation applicable to intermediate cases, the movement of the piston crushing the cylinder is studied theoretically, under the action of a force which is some function of the time, and the results of theory are compared with the data supplied by the registration of the law of the movement of the crusher piston under the action of the principal explosives. The maximum pressure due to the final crushing of the cylinder depends on the ratio of the time which separates the production of the maximum from the commencement of the movement, to the duration of the crushing of the cylinder, by a constant force acting without initial velocity upon the crushing piston. The duration of, and the law of the movement of the piston during crushing, is determined by means of a short and fine pointer of steel foil,

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attached to the piston of the crusher, which traces a curve on a moving cylinder; by this means movements have been registered which lasted only from 3 to 4 ten-thousandths of a second. For the experiments the mass and section of the piston were varied; the law of the development of the pressure was modified by employing the same explosive in different states, the maximum pressure being maintained uniform by keeping the same density of charge—that is, ratio of weight of explosive to the capacity of the eprouvette. A table of results is given.

E. F. B.

The Manufacture of Dynamite. By H. MÜNCH.

(Wochenschrift des österreichischen Ingenieur- und Architekten-Vereins, July 29th, 1882, p. 204.)

This Paper describes a visit made by the mining section of the Austrian Association of Engineers and Architects to the manufactory of dynamite at Pressburg. These works, which are the largest in Austria, were founded in 1875, and have since been increased, so that they are now capable of producing about 500 tons of dynamite yearly. The first operation in the manufacture of dynamite is the production of concentrated nitric acid (48 per cent.), which is used for the conversion of the glycerine into nitro-glycerine. This nitric acid is mixed with concentrated sulphuric acid, and the two are then raised by pneumatic pressure into the nitrating vessels. Here they are brought into contact with pure glycerine, which is allowed to run slowly into the apparatus. As any rise of temperature at this stage would be extremely dangerous, the vessel is cooled by means of cold water and compressed air. As soon as the thermometer indicates a temperature of 30° Centigrade (86° Fahrenheit) the flow of glycerine is interrupted, and the supply of cold water and compressed air increased. Should these precautions prove insufficient red fumes are given off by the liquid, and the workman is obliged to open a valve in the bottom of the vessel, through which the mixed acids and nitro-glycerine are precipitated into a large volume of cold water. In the neighbourhood of the nitrating house are buildings in which the nitro-glycerine is separated from the acid and washed. The purified nitro-glycerine, when mixed with soluble gun-cotton, forms blasting-gelatine. In the manufacture of the various kinds of dynamite the absorbent substances are mixed with the nitro-glycerine by special machinery, the resulting dynamite being then sifted, and afterwards made into cartridges 23 millimetres (0·9055 inch) or 26 millimetres (1·0236 inch) in diameter. These cartridges are subsequently coated with paraffin and packed in boxes, which are then ready for the market. The whole of the buildings are heated by hot water, and are connected by a network of pipes, hundreds of yards of which are sometimes

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destroyed by partial explosions. The waste sulphuric acid is used for the production of super-phosphate.

A number of experiments were carried out to test the explosive power of different preparations of nitro-glycerine. The method adopted was to place 20 grammes (308·647 grains) of the explosive in a bore-hole 23 millimetres (0·9055 inch) in diameter, and 120 millimetres (4·7244 inches) deep, made in the centre of a cylinder of lead 200 millimetres (7·8740 inches) in diameter and height. A detonator, to which a fuse was attached, was pushed down into the charge, and the bore-hole closed with clay, only retaining sufficient moisture to render it plastic.[1] The lead cylinder was placed in an iron frame between two steel plates, the fuse was lighted, and the ensuing detonation of the explosive produced a cavity in the lead. The cubical capacity of this cavity was then measured by water from a graduated vessel, and gave an indication of the power of the explosive.

W. F. R.

Sounding and Light-giving Buoys. By E. ALLARD.

(Annales des Ponts et Chaussées, 6th series, vol. iii., 1882, p. 605, 2 woodcuts.)

A description has been previously given of an automatic whistling buoy,[2] which was placed in front of Havre a few years ago. Owing to the success of this trial, eight of these buoys were purchased; and four of them were anchored, at Havre, Cape Grisnez, Cape La Hague, and Brest. Each buoy costs £350, exclusive of the anchor and chain.

An attempt has been made to construct buoys capable of giving light, in place of emitting sound, which would be of still greater value to sailors. Geissler's tubes, rendered luminous by a battery and Ruhmkorff's coil placed inside the buoy, have been tried, but without any practical success hitherto. Gas under compression, contained inside the buoy, supplying a burner placed in a lantern at the top of the buoy, has proved more satisfactory. The body of the buoy is similar in form to other buoys, but it is made of steel plates welded together, so that, without being too heavy, it may be able to sustain a considerable internal pressure. The gas is obtained from the distillation of mineral oil, and has the advantage over common gas of a greater illuminating power, and of being unaffected by compression. The pressure of the gas passing to the burner is regulated by a flexible membrane, stretched over the top of a cylinder, which is raised, by a pressure of over $\frac{3}{4}$ inch

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[1] Clay tamping gives irregular results on account of the difficulty of securing the same degree of compression in each case: when dry sand is substituted the figures obtained are much more regular, although not so high as when stiff clay is used.—W. F. R.

[2] Minutes of Proceedings Inst. C.E., vol. lvii., p. 377.

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of water beyond the atmospheric pressure, so as to move a lever which closes the aperture admitting the gas. The burner is situated in the centre of a small lenticular drum; and a lantern with double glass sides surrounds the apparatus. The external air is admitted, and the products of combustion expelled, by openings so contrived that water cannot enter the apparatus, or wind affect the light. A buoy of this type was anchored off Havre, and lighted on the 3rd of October, 1881; and the light went out for want of gas on the following 30th of January, having burnt for 2,839 hours. The capacity of the buoy is 13 cubic yards; the gas was under a pressure of 6 atmospheres at the commencement, and its rate of consumption was about $\frac{3}{4}$ cubic foot per hour. The light, which was given a red tinge, was visible to a distance of 5 miles; it had about the same intensity at the end as at the beginning; it was seen 93 times in 100 from various points of Havre, from $1\frac{1}{4}$ to $2\frac{1}{2}$ miles distant, and 63 times in 100 from La Hève, about $2\frac{1}{2}$ miles off. The buoy was exposed to three storms during the winter without being at all injured. Photometric experiments on shore indicated that the light exhibited by the buoy had an intensity of nearly $1\frac{1}{2}$ carcel, which, with an improved manufacture of the gas, would reach nearly 2 carcels. Owing, however, to the adherence of brine and other matters to the glass of the lantern, which could only be occasionally removed, it would not be safe to calculate in practice on more than an intensity of 1 carcel. In this case the luminous range would be $4\frac{3}{4}$ miles in weather of average transparency, and not less than $2\frac{3}{4}$ miles for more than a twelfth of the year; but if it was necessary to colour the light to mark the entrance channel, as might frequently be the case, the range would be reduced, in the case of red, to 2·3 miles and 2 miles; and for green to 1·9 and $1\frac{1}{2}$ mile respectively. A light-giving buoy, having a capacity of about 13 or 14 cubic yards, costs £410, exclusive of chain and anchorage. The cost of the gas, delivered at the quay, is 8·8*d.* per cubic yard under the ordinary pressure. The yearly cost of lighting the buoy is £8 16*s.*; but to this must be added the expense of refilling with gas periodically, and the maintenance of the buoy, which will probably exceed £40 per year. It is evident that this system of lighting might be extended to beacons which are difficult of access. An attempt is being made to unite the sounding and light-giving buoy in one, by making a portion of the current of air of the whistling buoy traverse a volatile liquid, and thus produce a carburetted gas suitable for burning in a lamp at the top of the buoy.

L. V. H.

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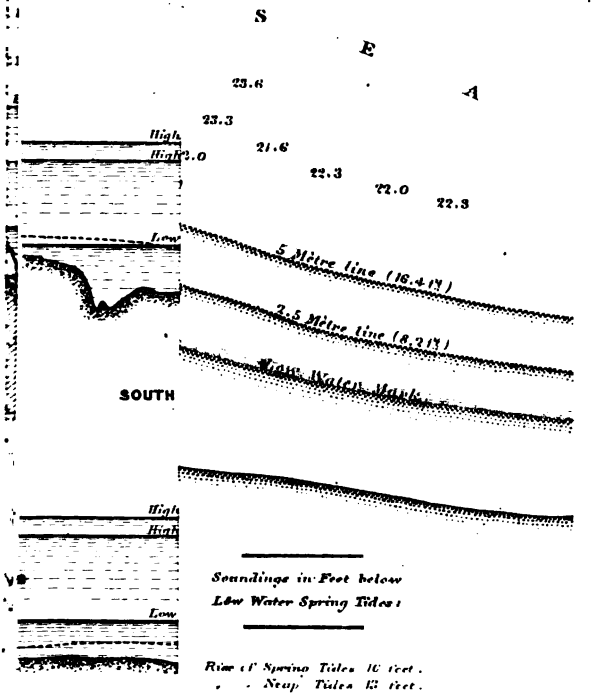
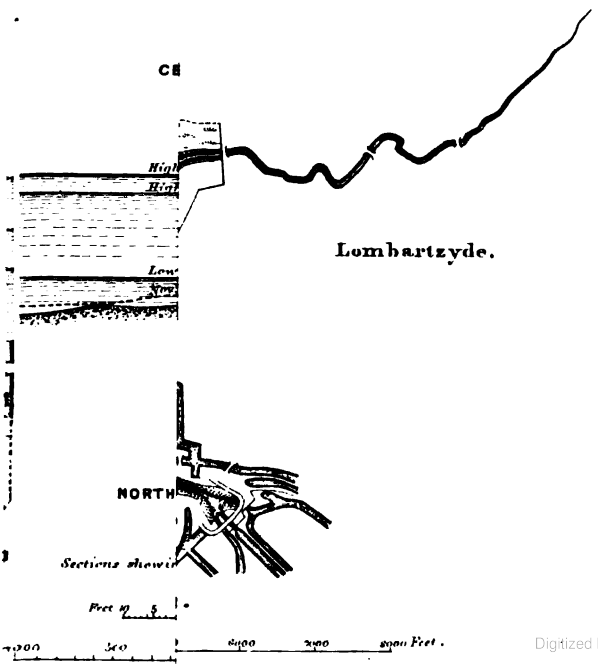


Rise of Spring Tides 16 feet.
" " Neap Tides 12 feet.



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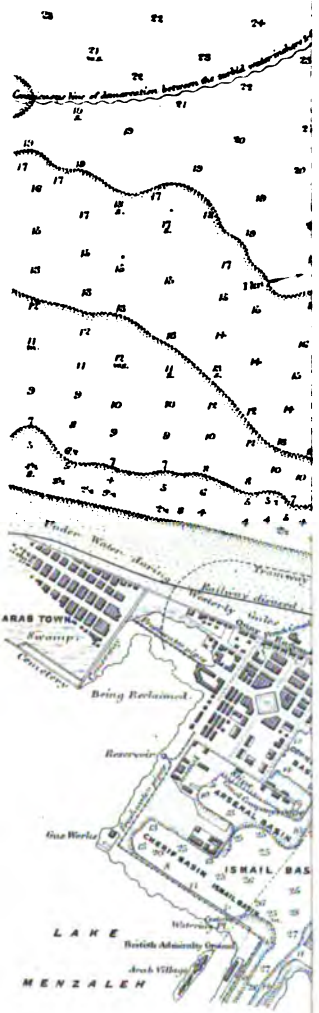

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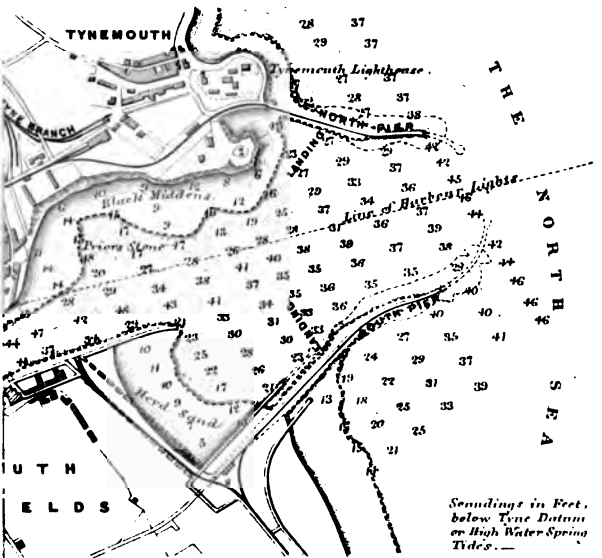
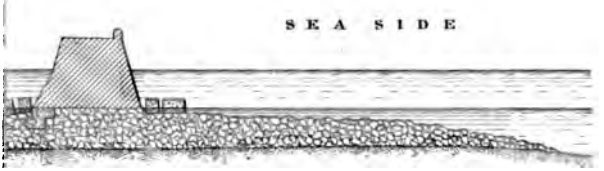


MOUTH OF THE RIVER TYNE.

Scale of Feet.
1000 2000 3000 4000 5000 6000 Feet.

Fig: 10.

MOUTH HARBOUR.



OF SOUTH BREAKWATER.

Scale of Feet.
100 150 200 250 Feet

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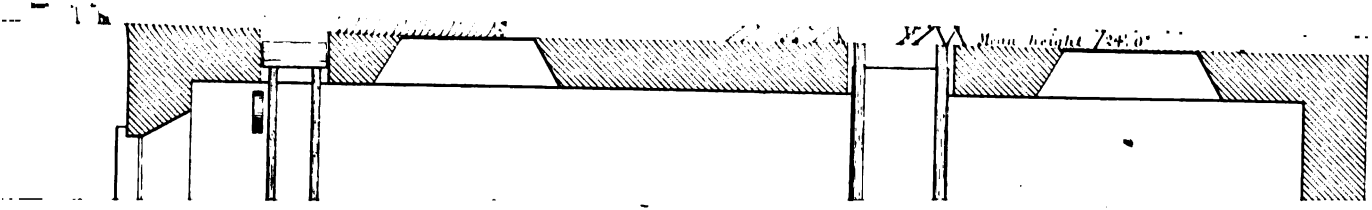

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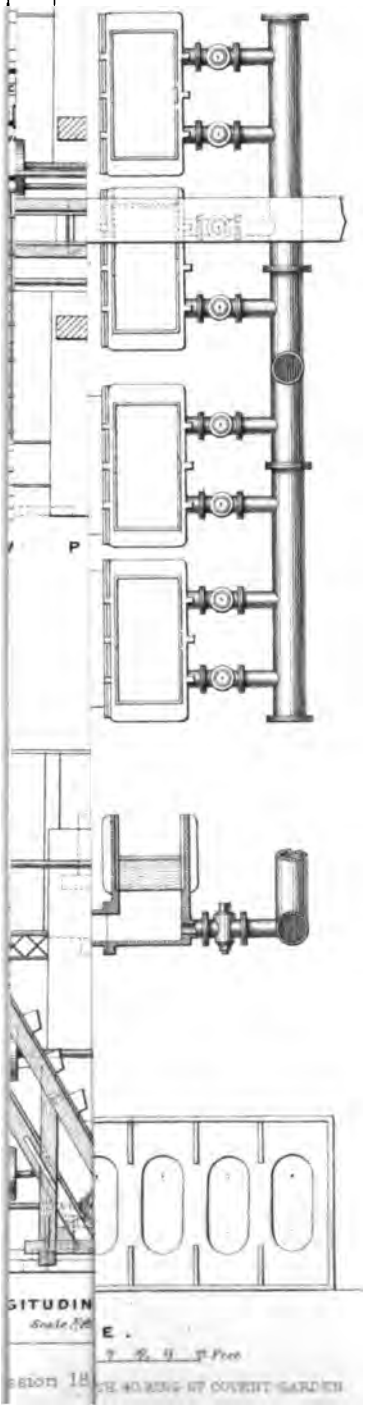

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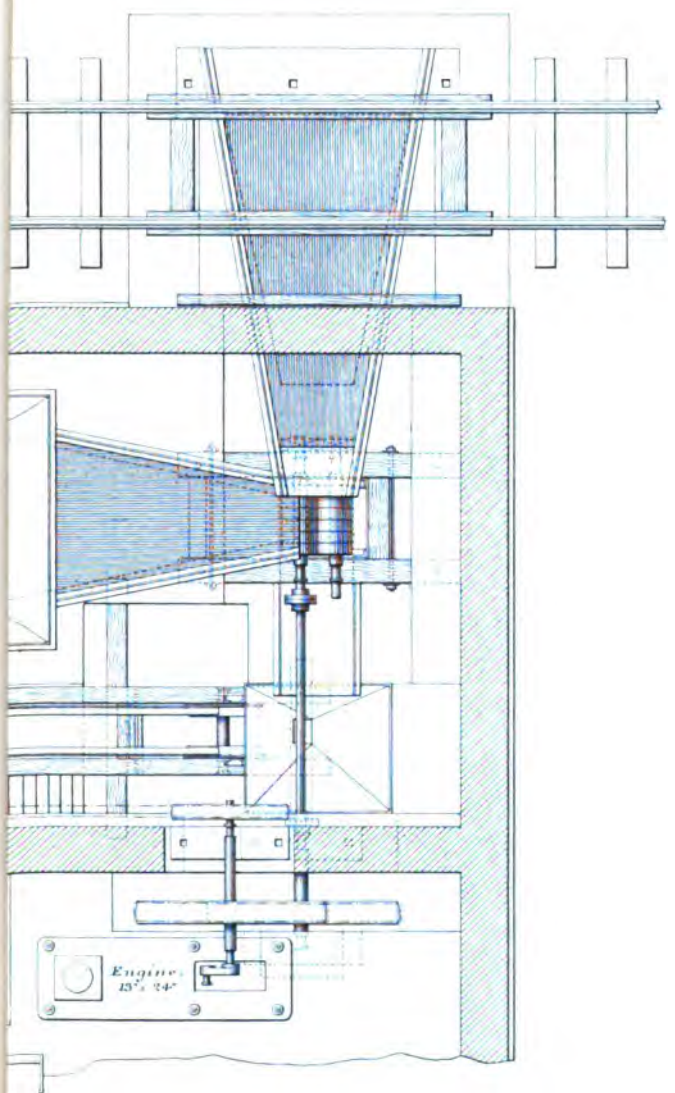

TOR, ROLLS, TIPPING CRADLE, &c.

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THOS REED & SON, LITH. 40 KING ST COVENT GARDEN

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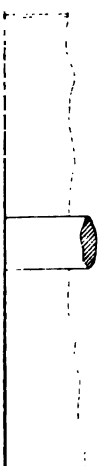

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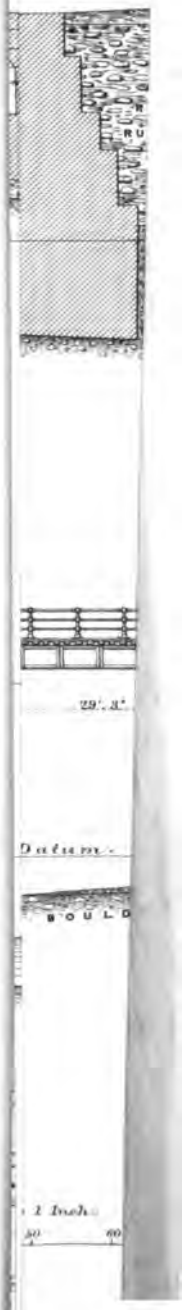
Fig :



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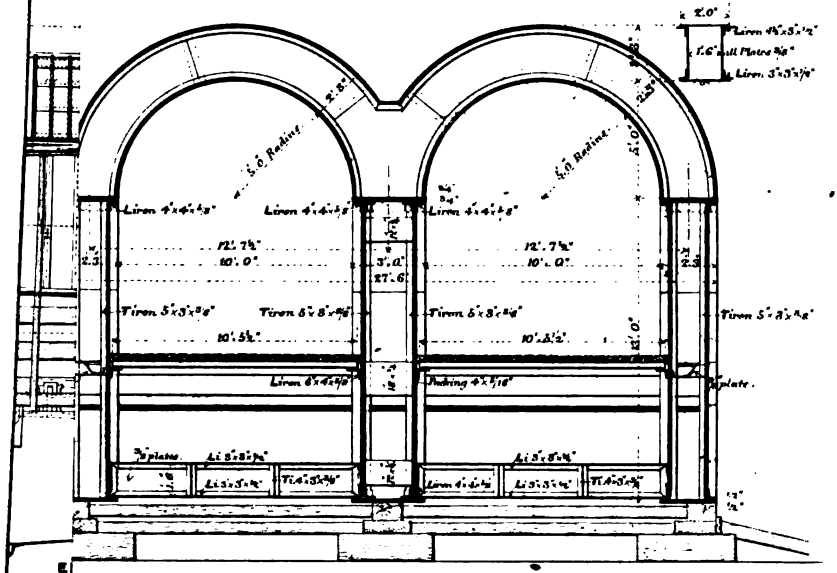
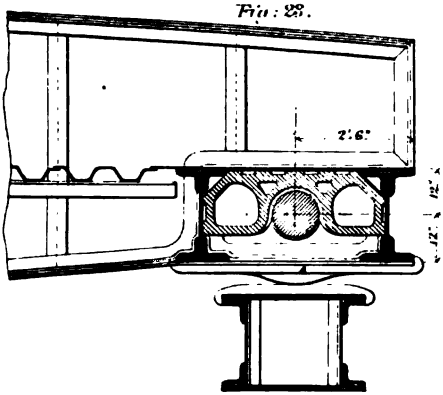


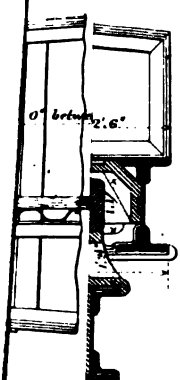
SECTION ON LINE A.B. FIG. 18.

Scale: 1/8 Inch. = 1 Foot.

0 1 2 3 4 5 10 15 20 Feet.

Fig: 25.





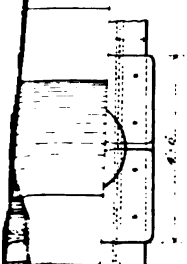
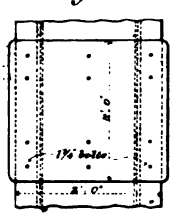


Fig: 26.



PLAN OF BEARING PIECE.

CKET.

DGE JOINTS AND CONNECTIONS.

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W. H. KELL & SON, LITH. 4 KING ST. COVENT GARDEN.

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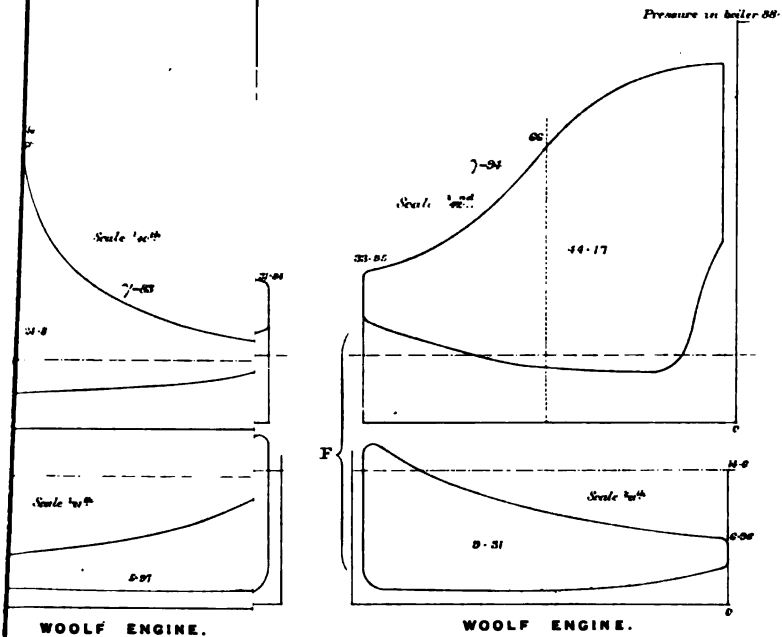
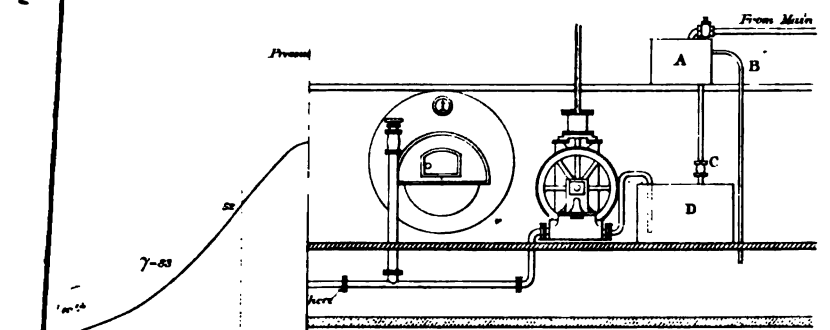


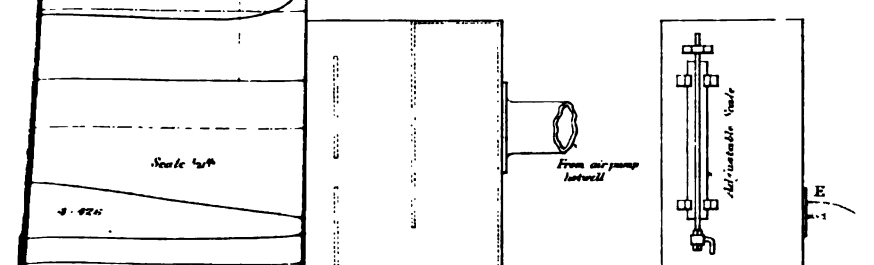
WOOLF ENGINE.

WOOLF ENGINE.



TS FOR MEASURING FEED WATER.

Scale 1/8 Inch = 1 Foot.



WOOLF ENGINE.

K FOR HOTWELL OVERFLOW.

Scale 3/8 Inch 1 Foot.

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THOS KELL & SON LATH 40 KING ST DOVER

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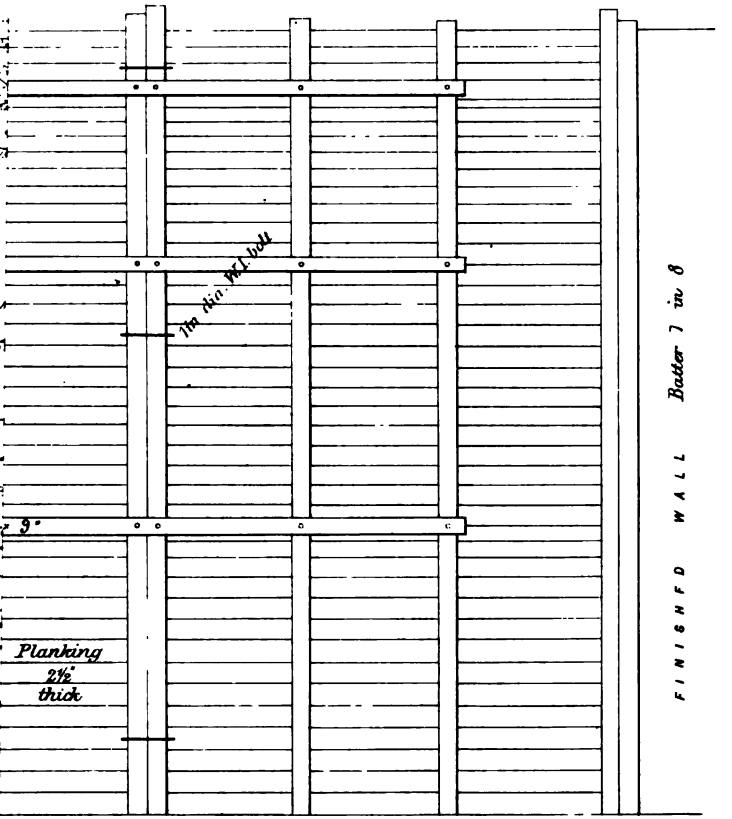
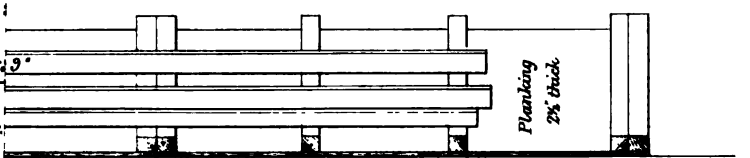
Fig. 9.



OF TIMBER MOULD FOR CONCRETE BUILDING.

Fig. 10.



BER MOULDS & W.I. STAYS FOR CONCRETE BUILDING.

Scale for Figs. 8, 9 & 10.

10 20 30 Feet

THOS KELL & SON, LITH. 40, KING ST. COVENT GARDEN

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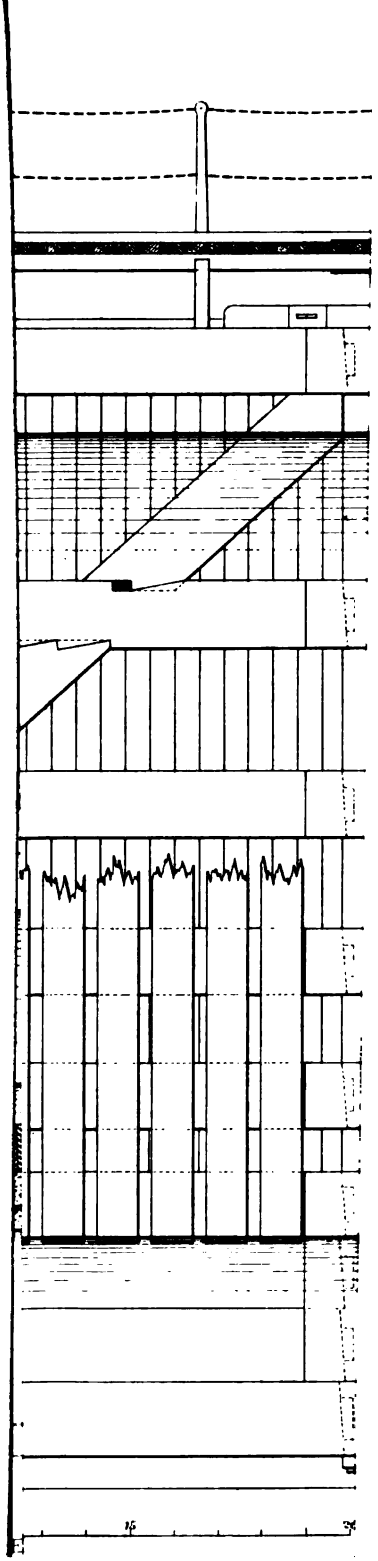

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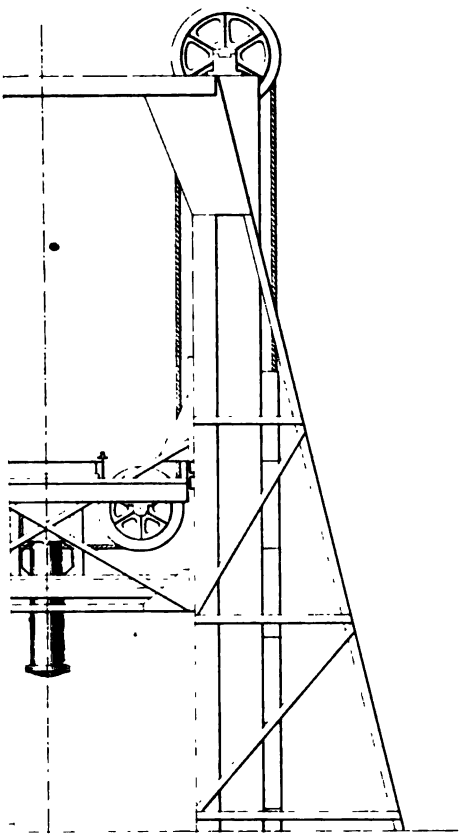
Fig: 20.



FRONT ELEVATION.

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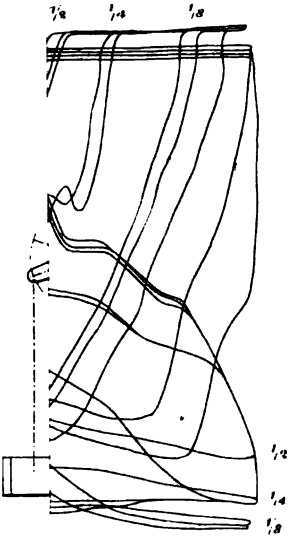

SECTION

OILER PRESSURE

Cylinder.—

Fat :

Tons.

Effect on Crank Pins

ED TURNING EFFECT

Cylinders. (Cranks at 90°)

ENCE :

Engines shown thus.....

on Guides. mistake.....

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